In the Specification:

Claim of Priority:

[0001] This application claims priority from provisional application entitled "DUAL INPUT AND OUTLET ELECTROSTATIC AIR TRANSPORTER-CONDITIONER," Application No. 60/340,288, filed December 13, 2001 and from Provisional Application entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH AN ENHANCED COLLECTOR ELECTRODE FOR COLLECTING MORE PARTICULATE MATTER," Application No. 60/340,462, filed December 13, 2001 under 35 U.S.C. 119(e), which applications are incorporated herein by reference. This application claims priority from provisional application entitled "FOCUS ELECTRODE, ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES," Application No. 60/306,479, filed July 18, 2001 under 35 U.S.C. 119(e), which application is incorporated herein by reference. This application claims priority from and is a continuation-in-part of U.S. Patent Application No. 09/924,624 filed August 8, 2001 which is a continuation of U.S. Patent No. 09/564,960 filed May 4, 2000, now U.S. Patent No. 6,350,417, which is a continuation-in-part of U.S. Patent Application No. 09/186,471 filed November 5, 1998, now U.S. Patent No. 6,176,977, all of which are incorporated herein by reference. This application claims priority from and is a Continuation-in-Part of U.S. Patent Application No. 09/730,499, filed December 5, 2000 which is a continuation of U.S. Patent Application No. 09/186,471, filed November 5, 1998, now U.S. Patent No. 6,176,977.

[0014] 13. U.S. Patent Application No. 10/074,082, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH AN UPSTREAM FOCUS ELECTRODE"; SHPR-01041USL

[0015] 14. U.S. Patent Application No. 10/074,209, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH TRAILING ELECTRODE"; SHPR-01041USM

[0016] 15. U.S. Patent Application No. 10/074,207, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH INTERSTITIAL ELECTRODE"; SHPR-01041USN

[0017] 16. U.S. Patent Application No. 10/074,208, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH ENHANCED COLLECTOR ELECTRODE"; SHPR-01041USO

[0018] 17. U.S. Patent Application No. 10/074,339, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH ENHANCED EMITTER ELECTRODE"; SHPR-01041USP

[0019] 18. U.S. Patent Application No. 10/074,096, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US4

[0020] 19. U.S. Patent Application No. 10/074,347, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED HOUSING CONFIGURATION AND ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US5

[0021] 20. U.S. Patent Application No. 10/074,379, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH

ENHANCED MAINTENANCE FEATURES AND ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US6

[0022] 21. U.S. Patent Application No. 10/074,827, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER WITH NON-EQUIDISTANT COLLECTOR ELECTRODES"; SHPR-01041USQ and

[0023] 22. U.S. Patent Application No. 10/074,103, filed herewith on February 12, 2002, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH A ENHANCED COLLECTOR ELECTRODE FOR COLLECTION OF MORE PARTICULATE MATTER". SHPR-01041USS.

[0028] The use of an electric motor to rotate a fan blade to create an airflow has long been known in the art. Unfortunately, such fans produce substantial noise, and can present a hazard to children who may be tempted to poke a finger or a pencil into the moving fan blade. Although such fans can produce substantial airflow, e.g., 1,000 ft^3/minute or more, substantial electrical power is required to operate the motor, and essentially no conditioning of the flowing air occurs.

[0029] It is known to provide such fans with a HEPA-compliant filter element to remove particulate matter larger than perhaps 0.3 μm. Unfortunately, the resistance to airflow presented by the filter element may require doubling the electric motor size to maintain a desired level of airflow. Further, HEPA-compliant filter elements are expensive, and can represent a substantial portion of the sale price of a HEPA-compliant filter-fan unit. While such filter-fan units can condition the air by removing large particles, particulate matter small enough to pass through the filter element is not removed, including bacteria, for example.

[0030] It is also known in the art to produce an airflow using electro-kinetic techniques, by which electrical power is directly converted into a flow of air without mechanically moving components. One such system is described in U.S. Patent No. 4,789,801 issued to Lee (1988), which is incorporated herein by reference. The '801 patent describes various devices to generate a stream of ionized air using so-called electro-kinetic techniques. In some applications, the electro-kinetic devices may be small enough to be handheld, and in other applications electro-kinetic devices may be large enough to condition the air in a room. In overview, electro-kinetic techniques use high electric fields to ionize air molecules, a process that may produce ozone (O_3) as a byproduct. Ozone is an unstable molecule of oxygen that is commonly produced as a byproduct of high voltage arcing. In appropriate concentrations, ozone can be a desirable and useful substance. But ozone by itself may not be effective to kill microorganisms such as germs, bacteria, and viruses in the environment surrounding the device.

[0031] Fig. 1A depicts a generic electro-kinetic device **10** to condition air. Device **10** includes a housing **20** that typically has at least one air input port **30** and at least one air output port **40**. Within housing **20** there is disposed an electrode assembly or system **50** comprising a first electrode array **60** having at least one electrode **70** and comprising a second electrode array **80** having at least one electrode **90**. System **10** further includes a high voltage generator **95** coupled between the first and second electrode arrays.

[0032] As a result, ozone and ionized particles of air are generated within device **10**, and there is an electro-kinetic flow of air in the direction from the first electrode array **60** towards the second electrode array **80**. In Fig. 1A, the large arrow denoted IN represents ambient air that can enter input port **30**. The small "x's" denote particulate matter that may be present in the incoming ambient air. The air movement

is in the direction of the large arrows, and the output airflow, denoted OUT, exits device **10** via port **40**. An advantage of electro-kinetic devices such as device **10** is that an airflow is created without using fans or other moving parts to create the airflow.

[0033] Preferably, particulate matter in the ambient air can be electrostatically attracted to the second electrode array **80**, with the result that the outflow (OUT) of air from device **10** not only contains ozone and ionized air, but can be cleaner than the ambient air. Thus, device **10** in Fig. 1A can function somewhat as a fan to create an output airflow, but without requiring moving parts. Ideally the outflow of air (OUT) is conditioned in that particulate matter is removed and the outflow includes appropriate amounts of ozone, and some ions.

[0034] As shown in Fig. 1B, system **50** includes an array of first ("emitter") electrodes or conductive surfaces **70** that are spaced-apart symmetrically from an array of second ("collector") electrodes or conductive surfaces **90**. The positive terminal of a generator such as, for example, pulse generator **95** that outputs a train of high voltage pulses (e.g., 0 to perhaps + 5 KV) is coupled to the first array, and the negative pulse generator terminal is coupled to the second array in this example. It is to be understood that the arrays depicted include multiple electrodes, but that an array can include or be replaced by a single electrode.

[0035] The high voltage pulses ionize the air between the arrays, and create an airflow from the first array toward the second array, without requiring any moving parts. Particulate matter **60** in the air is entrained within the airflow and also moves towards the second electrodes **90**. Much of the particulate matter **60** is electrostatically attracted to the surfaces of the second electrodes **90**, where it remains, thus conditioning the flow of air exiting system **50**. Further, the high voltage field present between the electrode

arrays can release ozone into the ambient environment, which can eliminate odors that are entrained in the airflow.

[0036] In the particular embodiment of Fig. 1B, first electrodes **70** are circular in cross-section, having a diameter of about 0.003" (0.08 mm), whereas the second electrodes **90** are substantially larger in area and define a "teardrop" shape in cross-section. The ratio of cross-sectional radii of curvature between the bulbous front nose of the second electrode and the first electrodes exceeds 10:1. As shown in Fig. 1B, the bulbous front surfaces of the second electrodes **90** face the first electrodes **70**, and the somewhat "sharp" trailing edges face the exit direction of the airflow. The "sharp" trailing edges on the second electrodes **90** promote good electrostatic attachment of particulate matter entrained in the airflow.

[0037] In another particular embodiment shown herein as Fig. 1C, second electrodes **90** are symmetrical and elongated in cross-section. The elongated trailing edges on the second electrodes **90** provide increased area upon which particulate matter entrained in the airflow can attach.

[0038] While the electrostatic techniques disclosed by the '801 patent are advantageous over conventional electric fan-filter units, further increased air transport-conditioning efficiency would be advantageous.

[0039] What is needed is a device to condition air in a room that can operate relatively silently to remove particulate matter in the air, that can preferably output appropriate amounts of ozone or no ozone, and that can also kill or reduce microorganisms such as germs, fungi, bacteria, viruses, and the like.

<u>Summary of the Invention:</u>

[0040] The present invention provides such an apparatus.

[0041] An aspect of the present invention is an electro-kinetic system for transporting and conditioning air without moving parts. An embodiment of the present invention includes an ion generator comprising first and second electrodes, or first and second conducting surfaces, electrically connected to the output ports of a high voltage generator. The second electrode or conducting surface can electrostatically collect dust and other particulate matter contained within the air.

[0042] Another aspect of the present invention is to increase the air cleaning per watt of electrical power consumed. An embodiment of the present invention has two intake and two outlet ports. By increasing the number of intakes and outlets, a larger volume of air can be moved and conditioned without having to expend more energy to maintain the airflow velocity.

[0043] In another aspect of the present invention, two or more ion generating units are enclosed in a housing having dual inlets and dual outlets. Such an arrangement can increase airflow without an increase in voltage levels or voltage differentials in the ion generating unit.

[0044] Another embodiment of the invention includes one or more second electrodes having a non-linear tail section. The tail section increases the width and surface area of the second electrode. As a result, there is a larger surface area to attract and capture particles.

[0045] Still another aspect of the present invention is to kill microorganisms within the airflow. An embodiment of the invention has a germicidal lamp, located upstream of the ion generator, to kill microorganisms.

[0046] Other objects, aspects, features and advantages of the invention will appear from the following description in which preferred embodiments have been set forth in detail, in conjunction with the accompanying drawings and also from the following claims.

Brief Description of the Drawings:

[0047] FIGS. 1A-1C; Fig. 1A is a plan view of an electro-kinetic air transporter-conditioner system, according to the prior art; Fig. 1B is a plan view of another embodiment of first and second electrode arrays, according to the prior art; Fig. 1C is yet another embodiment of the first and second electrode arrays, according to the prior art;

[0048] FIGS. 2A-2B; Fig. 2A is a perspective view of an embodiment of the present invention; Fig. 2B is a perspective view of the embodiment in Fig. 2A, illustrating the removable second array of electrodes;

[0049] FIGS. 3A-3E; Fig. 3A is a perspective view of another embodiment of the present invention; Fig. 3B is a cut-away view of the embodiment shown in Fig. 3A, illustrating the ion generator contained within the housing; Fig. 3C is a cut-away plan view of the embodiment shown in Fig. 3B; Fig. 3D is a perspective view of yet another embodiment of the present invention; Fig. 3E is still another embodiment of the present invention;

[0050] FIGS. 4A-4C; Fig. 4A is an electrical block diagram of an embodiment the ion generator, according to the present invention; Fig. 4B is a partial electrical block diagram of another embodiment of the present invention; Fig. 4C is a partial electrical block diagram of still another embodiment of the present invention depicted in Fig. 4B;

[0051] FIGS. 5A-5J; Fig. 5A is a perspective view of an embodiment of the electrode assembly, according to the present invention; Fig. 5B is a plan view of the embodiment shown in Fig. 5A; Fig. 5C is a perspective view of another embodiment of the electrode assembly; Fig. 5D is still another embodiment of the electrode assembly; Fig. 5E is yet another embodiment of the electrode assembly; Fig. 5F is a plan

view of the embodiment shown in Fig. 5E; Fig. 5G is still a further embodiment of the electrode assembly; Fig. 5H is a plan view of another embodiment of the invention; Fig. 5I is a perspective view of yet another embodiment of the electrode assembly; Fig. 5J is a plan view of the embodiment shown in Fig. 5I;

[0052] FIGS. 6A-6B; Fig. 6A is a perspective view of yet another embodiment of the electrode assembly, according to the invention; Fig. 6B is a plan view of a further embodiment of the electrode assembly;

[0053] FIGS. 7A-7D; Fig. 7A is a perspective view of another embodiment of the electrode assembly, according to the present invention; Fig. 7B is a perspective view of an embodiment modified from that shown in Fig. 7A; Fig. 7C is a perspective view of yet another embodiment modified from that shown in Fig. 7A; Fig. 7D is still another embodiment of the electrode assembly;

[0054] FIGS. 8A-8C; Fig. 8A is a perspective view of yet another embodiment of the electrode assembly, according to the present invention; Fig. 8B is a perspective view of an embodiment modified from that shown in Fig. 8A; Fig. 8C is a perspective view of still another embodiment of the electrode assembly;

[0055] FIGS. 9A-9C; Fig. 9A is a perspective view of still another embodiment of the electrode assembly, according to the present invention; Fig. 9B is a perspective view of another embodiment of the electrode assembly; Fig. 9C is a perspective view of yet another embodiment of the electrode assembly;

[0056] FIGS. 10A-10C; Fig. 10A is a perspective view of yet another embodiment of the electrode assembly, according to the present invention; Fig. 10B is a perspective view of an embodiment modified from that show in Fig. 10A; Fig. 10C is a perspective view of another embodiment modified from that shown in Fig. 10A;

[0057] FIGS. 11A-11D; Fig. 11A is a perspective view of still another embodiment of the electrode assembly, according to the present invention; Fig. 11B is a plan view of the embodiment shown in Fig. 11A; Fig. 11C is a perspective view of an embodiment of the invention modified from that shown in Fig. 11B; Fig. 11D depicts another embodiment of the invention;

[0058] FIGS. 12A-12F; Fig. 12A is a plan view of still another embodiment of the electrode assembly, according to the present invention; Fig. 12B is a plan view of an embodiment modified from that shown in Fig. 12A; Fig. 12C is a plan view of yet another embodiment of the electrode assembly; Fig. 12D is a plan view of an embodiment modified from that shown in Fig. 12C; Fig. 12E is a plan view of a further embodiment of the electrode assembly; Fig. 12F is a plan view of an embodiment modified from that shown in Fig. 12E;

[0059] FIGS. 13A-13C; Fig. 13A is a perspective view of another embodiment of the electrode assembly, according to the present invention; Fig. 13B is a perspective view of still another embodiment of the electrode assembly; Fig. 13C is a perspective view of yet another embodiment of the electrode assembly; and

[0060] FIGS. 14A-14C; Fig. 14A is a plan view of another embodiment of the present invention; Fig. 14B is an embodiment modified of that shown in Fig. 14A; Fig. 14C is an another embodiment modified of that shown in Fig. 14A.

Detailed Description of the Present Invention:

Overall Air Transporter-Conditioner System Configuration:

[0061] Figs. 2A and 2B depict an electro-kinetic air transporter-conditioner system **100** whose

housing **102** includes preferably rear-located intake vents or louvers **104** and preferably front located exhaust vents **106**, and a base pedestal **108**. Preferably the housing is freestanding and/or upstandingly vertical and/or elongated. Internal to the transporter housing is an ion generating unit **160**, preferably powered by an AC:DC power supply that is energizable or excitable using switch **S1**. Switch **S1**, along with the other below described user operated switches, is conveniently located at the top **103** of the unit **100**. Ion generating unit **160** is self-contained in that other than ambient air, nothing is required from beyond the transporter housing, save external operating potential, for operation of the present invention.

[0062] The upper surface **103** of housing **102** includes a user-liftable handle member **112** to which is affixed a second array **240** of collector electrodes **242**. The housing **102** also contains a first array of emitter electrodes **230**, or a single first electrode shown here as a single wire or wire-shaped electrode **232**. (The terms "wire" and "wire-shaped" shall be used interchangeably herein to mean an electrode either made from a wire or, if thicker or stiffer than a wire, having the appearance of a wire.) In the embodiment shown, lifting member **112** lifts second array electrodes **240** upward, causing the second electrode to telescope out of the top of the housing **102** and, if desired, out of unit **100** for cleaning, while the first electrode array **230** remains within unit **100**. As is evident from the figure, the second array of electrodes **240** can be lifted vertically out from the top **103** of unit **100** along the longitudinal axis or direction of the elongated housing **102**. This arrangement with the second electrodes removable from the top **103** of the unit **100**, makes it easy for the user to pull the second electrodes **242** out for cleaning. In Fig. 2B, the bottom ends of second electrodes **242** are connected to a member **113**, to which is attached a mechanism **500**, which includes a flexible member and a slot for capturing and cleaning the first electrode **232**, whenever handle member **112** is moved upward or downward by a user. The first and second arrays of

electrodes are coupled to the output terminals of ion generating unit **160**, as shown in Figs. 4A-4B.

[0063] The general shape of the embodiment of the invention shown in Figs. 2A and 2B is that of a figure eight in cross-section, although other shapes are within the spirit and scope of the invention. The top-to-bottom height of the preferred embodiment is in one preferred embodiment, 1 m, with a left-to-right width of preferably 15 cm, and a front-to-back depth of perhaps 10 cm, although other dimensions and shapes can of course be used. A louvered construction provides ample inlet and outlet venting in an economical housing configuration. There need be no real distinction between vents **104** and **106**, except their location relative to the second electrodes. These vents serve to ensure that an adequate flow of ambient air can be drawn into or made available to the unit **100**, and that an adequate flow of ionized air that includes appropriate amounts of O_3 flows out from unit **100**.

[0064] As will be described, when unit **100** is energized with **S1**, high voltage or high potential output by ion generator **160** produces ions at the first electrode, which ions are attracted to the second electrodes. The movement of the ions in an "IN" to "OUT" direction carries with the ions air molecules, thus electro-kinetically producing an outflow of ionized air. The "IN" notation in Figs. 2A and 2B denote the intake of ambient air with particulate matter **60**. The "OUT" notation in the figures denotes the outflow of cleaned air substantially devoid of the particulate matter, which particulates matter adheres electrostatically to the surface of the second electrodes. In the process of generating the ionized airflow appropriate amounts of ozone (O_3) are beneficially produced. It may be desired to provide the inner surface of housing **102** with an electrostatic shield to reduces detectable electromagnetic radiation. For example, a metal shield could be disposed within the housing, or portions of the interior of the housing can be coated with a metallic paint to reduce such radiation.

Dual Inlet and Dual Outlet Electro-Static Air Transporter-Conditioner:

[0065] Referring now to Figs. 3A-3B, the unit **200** has a housing **210** with two intake areas **204a** and **204b** and two exit areas **206a** and **206b**. The housing **210** is preferably manufactured from ABS plastic. Housing **210** is preferably substantially shorter than the housing of unit **100**. However, the unit **200** has a substantially larger body (i.e. the cross-section in plan view is substantially larger) in order, as described below to, accommodate two ion generating units. With two ion generating units, more particles can be removed from the airflow with lower or no increase in voltage or voltage differential across the electrodes of the ion generating units and with thus less generation of ozone. It is within the scope and spirit of the present invention to manufacture the housing **210** from other material such as, but not limited to, aluminum or stainless steel. If the housing **210** contains a germicidal lamp **290** (to be described later), the housing **210** must be manufactured from a material that will not deteriorate or degrade from exposure to ultraviolet light. By way of example only, such material may be CYCOLAC® ABS plastic, manufactured by General Electric Plastics.

[0066] A first inlet area or vent **204a** is located on the top surface **203** of the housing **210**, and a second inlet area or vent **204b** is located on the bottom surface **205** of the housing **210**. It is to be understood that with a bottom inlet the housing has legs (not shown) which elevate the housing above the surface upon which it rests. Preferably, the first inlet vent **204a** is located in the center of the top surface **203**. Similarly, the second inlet vent **204b** is preferably located in the center of the bottom **205**. As is evident from the Fig. 3A the inlets cover a large part of the area of the top of the housing and the bottom of the housing. In particular in this embodiment, only a peripheral margin of the top of the housing does not comprise an inlet. The same is true of the inlet in the bottom of the housing. These large inlets allow for

an increased volume of airflow. Further, in the peripheral margin of the top surface are located the controls and indicators and the handle for removing the second collector electrode of the ion generators and in another embodiment the germicidal lamps. As will become apparent later, the air is preferably brought into the center of the housing **210** with the two electrode assemblies **220** (to be described later) located downstream towards the outlet vents **206a** and **206b**. The inlet vents **204a** and **204b** are located "upstream" of each of the two electrode assembly **220** so that in a preferred embodiment the air travels the shortest path possible between the inlet and outlet. The outlet vents **206a, 206b** are preferably located directly downstream of each ion generator so that the airflow created by each electrode assembly **220** may have a separate exit out of the housing **210**. The outlet vents are located through the side peripheral wall of the housing between the top and bottom. Preferably the outlet vents are located at the ends of the oval-shaped housing. The outlet can extend around the ends to the flatter side of the oval if necessary to increase the volume of air that flows therethrough in order to match the intake of air through the inlet vents. The inlet vents **204a, 204b** as shown in Figs. 3A-3B are elliptical or oval in shape. It is within the scope of the present invention for the inlet vents **204a, 204b** to include other shapes such as, but not limited to, circular, rectangular, and hexagonal. Air entering the unit **200** is shown by the large arrow labeled "IN." Air exiting the unit **200** is shown by a large arrow labeled "OUT". The two inlet vents **204a, 204b** allows, a greater volume of air to enter the unit **200**. As previously mentioned, the air contains particles, such as dust, which are removed by the unit **200**. The more air conditioned or cleaned by the unit **200**, the greater the number of particles removed from the air.

[0067] As indicated above the unit **200** also has two outlet vents to provide an outlet for each ion generator disposed within the housing **200**. The two outlet vents **206a, 206b** are located along the side

wall **207**, and are preferably opposite one another. The air passing through the housing **210** could be conditioned and/or cleaned by a single electrode assembly **220** as in previous air conditioners (see Figs. 2A-2B). However, a single electrode assembly **220** will not efficiently condition/clean the increased volume of air brought into the housing **210** through the two inlet vent **204a, 204b**. By way of example only, the increased airflow can pass more particles through the electrode assembly **220**. Accordingly, in a preferred embodiment, and as indicated above, the housing **210** contains two electrode assemblies **220** to efficiently condition/clean the increased airflow.

[0068] Both the inlet vents **204a, 204b** and the outlet vent **206a, 206b** are partially covered by fins or louvers **212**. Each fin **212** is a thin ridge, spaced-apart from the next fin **212**, so that each fin **212** creates minimal resistance as air flows through the housing **210**. In this embodiment, as in the embodiment of Figs. 3A, the fins **212** covering the inlet vents **204a** and **204b** are aligned along the long axis of the oval or elliptical cross-section of the housing **210**. This configuration does not allow an individual to look side-to-side through the inlet **204a** or **204b** and directly view the inner side wall **211**. The fins **212** covering the outlet vents **206a** and **206b** are preferably elongated and vertically oriented and parallel to the upstanding housing **210** of the unit and the electrodes, and particularly and preferably are parallel to the second collector electrodes (described below) within the electrode assembly. Accordingly in a preferred embodiment the inlet louvers, the outlet louvers, and the second collector electrodes are all parallel. Of course none of the above could be parallel in other embodiments of the invention. The outlet fins are aligned to give the unit **200** a "see through" appearance. Thus, a user can "see through" the unit **200** by looking into outlet **206a** and out of the outlet **206b** or vice versa. The user will see no moving parts within the housing **210**, but just a quiet unit that cleans air passing therethrough.

[0069] An electro-kinetic air transporter-conditioner having two intake areas **204a, 204b** is an improvement over previous models. An electro-kinetic air conditioner-transporter draws air into the housing **210** at a fixed volumetric air rate (ft^3/sec). The volumetric air rate is proportional to the area of the inlet of the housing **202**. For example, as shown in Fig. 2A-2B, the volumetric air rate of this embodiment is proportional to the area of the inlet **104**. The volumetric air rate of unit **100** is constrained by the area of the single inlet **104**. In contrast, the embodiment in Fig. 3A has two inlets **204a, 204b**. Accordingly, if the airflow velocity is similar between the embodiments shown in Fig. 2A and 3A, the embodiment of unit **200**, as shown in Fig. 3A, will draw more air into the housing **210**. Since more air can travel through the housing **210** shown in Fig. 3A, particles are brought into the housing **210**, and collected by the electrode assembly **220**, in a quicker fashion than a unit with only a single inlet and outlet.

[0070] This phenomenon can also be explained by an enlarged catchment area formed around the housing **210**. A catchment area is defined as the horizontal planar area at the height of the top surface **203** or the bottom surface **205** of the housing **210**. The catchment area is where a rising stream of smoke will be drawn into the housing **210** through the inlet vents **204a** or **204b**, instead of continuing vertically into the room. The catchment radius **R** is the distance between the outer edge of the inlet vents **204a** or **204b** of the device **200** and the outer margin of the catchment area. The catchment radius **R** of an air transporter-conditioner as shown in Figs. 2A-2B extends only a few inches upstream from the intake of the device. The catchment area of the unit **200**, as shown as **R** in Fig. 3B, extends approximately three times farther from the intake of prior devices. Further, the presence of catchment areas on each of the two sides **203, 205** of the housing **210** essentially doubles the effectiveness of the unit **200** in comparison to other transporter-conditioners.

[0071] With two larger inlet vents **204a, 204b,** the intake air flows more slowly than it would be if it were funneled and accelerated through a single inlet. This means that less energy is needed to move air through the intakes **204a, 204b**, or alternatively, that for a given energy expenditure, more air is moved. Since energy required to maintain air velocity is proportional to the linear airflow velocity, energy savings is realized. Alternatively, additional volumemetric airflow, for a given energy expenditure, can result in energy savings. With larger inlets and outlets, there is more airflow without increasing the voltage or voltage potential across the electrode of the ion generating unit. In another embodiment, increased airflow can be realized with an increased voltage potential across the ion generator unit. However, this may require greater energy expenditure and may generate more ozone. In the present embodiment with dual ion generation units, and with dual inlets and outlets, a greater volume of air is cleaned at the same or lower voltage potential than in previous embodiments.

[0072] There are other dividends of a slow intake airflow velocity. For example, slow-moving particles suspended in the intake air are likely to be captured on the trailing sides **244** of the collector electrodes **242** before the airflow exits the unit **200**. A longer dwell time in the unit **200** also means that, if the device **200** is equipped with a germicidal UV lamp **290**, microbes suspended in the intake air will spend more time in proximity to the lamps, and will be more effectively killed (described hereinafter).

[0073] Improvements are also due to an increased cross-sectional area of the outlet vents **206a, 206b**. For a given degree of air cleaning, the airflow velocity through the outlet vents **206a, 206b** of the device **200** is slower than the velocity of the previous models. Preferably wider spacing between second electrodes **242** gives rise to a greater total cross-sectional outlet **206a, 206b**, and the presence of two separate outlet vents **206a, 206b** effectively doubles the outflow. Increasing the spacing between

electrodes **242** slightly diminishes the linear outflow velocity. It is believed, however, that the gain in airflow cross-sectional area is increased substantially more than the reduction in flow velocity. For example, widening the distance **Y2** (see Fig. 5A) from 1" to 1.25" was found to reduce the airflow velocity by less than 5%, while the cross-sectional area of the airflow was increased by 25%.

[0074] Fig. 3A further illustrates the operating controls for the device **200** on the peripheral margin. The following discussions can be more fully appreciated in conjunction with the electrical schematic of Figs. 4A and the accompanying description.

[0075] Located on top surface **203** of the housing **210** is an airflow speed control dial **214**, a boost button **216,** a function dial **218**, and a cleaning/overload light **219**. The airflow speed control dial **214** has three settings from which a user can choose: LOW, MEDIUM, and HIGH. The airflow rate is proportional to the voltage differential between the electrodes or electrode arrays in the ion generators. The LOW, MEDIUM, and HIGH settings generate a different predetermined voltage difference between the first and second arrays within the ion generator. For example, the LOW setting will create the smallest voltage difference, while the HIGH setting will create the largest voltage difference. The LOW setting will cause the device **200** to generate the slowest airflow rate, while the HIGH setting will cause the device **200** to generate the fastest airflow rate.

[0076] The function dial **218** enables a user to select "Ionic," "Ionic/UV," or "Off." When the function dial **218** is set to the "Ionic" setting, the unit **200** will function as an electrostatic air transporter-conditioner, creating an airflow from the inlets **204a, 204b** to the outlets **206a, 206b** removing the particles within the airflow. The germicidal lamp **290** (described below) does not operate when the function dial **218** is set to "Ionic." When the function dial **218** is set to the "Ionic/UV" setting, the device **200** will function

as an electrostatic air transporter-conditioner, creating an airflow from the inlets **204a**, **204b** to the outlets **206a**, **206b**, removing the particles within the airflow. In addition, the "Ionic/UV" setting activates the germicidal lamp **290** to additionally remove or kill bacteria within the airflow. The device **200** will not operate when the function dial **218** is set to the "Off" setting.

[0077] As previously mentioned, the device **200** preferably generates small amounts of ozone to reduce odors within the room. If there is an extremely pungent odor within the room, or a user would like to temporarily accelerate the rate of cleaning, the device **200** has a boost button **216**. When the boost button **216** is pressed, the device **200** will temporarily increase the airflow rate to a predetermined maximum rate, and generate a higher amount of ozone. In a preferred embodiment, pressing the boost button **216** will increase the airflow rate and ozone production continuously for 5 minutes. This time period may be longer or shorter. At the end of the preset time period (e.g., 5 minutes), the device **200** will return to the airflow rate previously selected by the control dial **214**.

[0078] The cleaning/overload light **219** indicates if the second electrodes **242** require cleaning, or if arcing between the first and second electrode arrays has occurred. The cleaning/overload light **219** may illuminate either amber or red in color. The light **219** will turn amber if the device **200** has been operating continuously for more than two weeks and the second array **240** has not been removed for cleaning within the two week period. The amber light is controlled by the two week time circuit **130** (see Fig. 4B) which is connected to the power setting circuit **122**. The device **200** will continue to operate after the light **219** turns amber. The light **219** is only an indicator. To reset the light **219**, the second array **240** must be removed completely from the unit **200**, and then placed back into the unit **200**. The timer circuit **130** (see Fig. 4B) will reset and begin counting a new two week period.

[0079] The light **219** will turn red to indicate that arcing has occurred between the first array **230** and the second array **240** as sensed by a sensing circuit **132**. When arcing occurs, the device **200** will automatically shut itself off. The device **200** cannot be restarted until the device **200** is reset. For the device **200** to be reset, the second array **240** may be removed from the housing **210**, preferably after the unit is turned off. The second electrode array **240** should then be cleaned and placed back into the housing **210**. After placing the second array **240** back into the housing **202**, turn the unit **200** on and if no arcing occurs this time, the device **200** will operate and generate an airflow. If the arcing between the electrodes continues, the device **200** will again shut itself off.

[0080] Also on the top surface of the housing are located handle **212** which are used for lifting out through the top of the housing the second collector electrodes of the ion generating electrode assembly units for cleaning. This is accomplished in much the same manner as the second collector electrode are removed from the unit **100** depicted in Fig. 2B.

<u>Dual Ion Generating Units for Dual Inlet and Dual Outlet Air Transporter-Conditioner:</u>

[0081] Referring now to Fig. 3C, the housing **210** contains two ion generators **220**. Preferably, both ion generators **220** are similar. It is within the scope and spirit of the invention for the ion generators **220** to have different configurations. By way of example, and as shown in Fig. 3C, each ion generator **220** has a first array of electrodes **230** including a single wire-shaped electrode **232**, and a second array of electrodes **240** including two "U"-shaped electrodes **242** having a tail section **246**. The tail sections **246** can be directed in the same direction and be parallel as depicted, or the tail sections can be configured to diverge from each other in order to form a "V" or "Y" configuration adjacent to the outlet vents. It is within

the scope of the present invention for the first and second array **230**, **240** to include more than one electrode and also to comprise other configurations as described below (see Figs. 5A-13C). Thus, any of the other many ion generator units described and depicted below can be substituted for the ion generating units depicted in Fig. 3C. Located between the two ion generators **220** is a focus or leading electrode **224** (described hereinafter). In this case, the two ion generating units **220** share a focus electrode **224**. However, in other embodiments the focus electrode **224** can be eliminated or the ion generating unit can have multiple focus electrodes.

[0082] In the various electrode assemblies to be described herein, the first electrode **232** is preferably fabricated from tungsten. Tungsten is sufficiently robust to withstand cleaning, has a high melting point to retard breakdown due to ionization, and has a rough exterior surface that seems to promote efficient ionization. On the other hand, second electrode **242** preferably will have a highly polished exterior surface to minimize unwanted point-to-point radiation. As such, electrodes **242** preferably are fabricated from stainless steel or brass, among other materials. The polished surface of electrodes **242** also promotes ease of electrode cleaning. Understandably, the material for electrodes **232** and **242** should conduct electricity, be resistant to corrosive effects from the application of high voltage, yet be strong enough to be cleaned.

[0083] In contrast to the prior art electrodes disclosed by the '801 patent, electrodes **232** and **242**, are light weight, easy to fabricate, and lend themselves to mass production. Further, electrodes **232** and **242** described herein promote more efficient generation of ionized air, and appropriate amounts of ozone, (indicated in several of the figures as O_3).

Electrical Circuit for the Electro-Kinetic Device:

[0084] As best seen in Fig. 4A, ion generating unit **160** for the embodiment of Figs. 2A-3C includes a high voltage generator unit **170** and circuitry **180** for converting raw alternating voltage (e.g., 117 VAC) into direct current ("DC") voltage. Circuitry **180** preferably includes circuitry controlling the shape and/or duty cycle of the generator unit output voltage (which control is altered with user switch **S2**). Circuitry **180** preferably also includes a pulse mode component, coupled to switch **S3**, to temporarily provide a burst of increased output ozone. Circuitry **180** can also include a timer circuit and a visual indicator such as a light emitting diode ("LED"). The LED or other indicator (including, if desired, an audible indicator) signals when ion generation quits occurring. The timer can automatically halt generation of ions and/or ozone after some predetermined time, e.g., 30 minutes.

[0085] The high voltage generator unit **170** preferably comprises a low voltage oscillator circuit **190** of perhaps 20 KHz frequency, that outputs low voltage pulses to an electronic switch **300**, e.g., a thyristor or the like. Switch **300** switchably couples the low voltage pulses to the input winding of a step-up transformer **T1**. The secondary winding of **T1** is coupled to a high voltage multiplier circuit **310** that outputs high voltage pulses. Preferably the circuitry and components comprising high voltage pulse generator **170** and circuit **180** are fabricated on a printed circuit board that is mounted within housing **102**.

[0086] Output pulses from high voltage generator **170** preferably are at least 10 KV peak-to-peak with an effective DC offset of, for example, half the peak-to-peak voltage, and have a frequency of, for example, 20 KHz. Frequency of oscillation can include other values, but frequency of at least about 20KHz is preferred as being inaudible to humans. If pets will be in the same room as the unit **100**, it may be desired to utilize and even higher operating frequency, to prevent pet discomfort and/or howling by the pet. The

pulse train output preferably has a duty cycle of for example 10%, which will promote battery lifetime if live current is not used. Of course, different peak-peak amplitudes, DC offsets, pulse train waveshapes, duty cycle, and/or repetition frequencies can be used instead. Indeed, a 100% pulse train (e.g., an essentially DC high voltage) may be used, albeit with shorter battery lifetime. Thus, generator unit **170** for this embodiment can be referred to as a high voltage pulse generator. Unit **170** functions as a DC:DC high voltage generator, and could be implemented using other circuitry and/or techniques to output high voltage pulses that are input to electrode assembly **220**.

[0087] As noted, outflow (OUT) preferably includes appropriate amounts of ozone that can destroy or at least substantially alter bacteria, germs, and other living (or quasi-living) matter subjected to the outflow. Thus, when switch **S1** is closed and the generator **170** has sufficient operating potential, pulses from high voltage pulse generator unit **170** create an outflow (OUT) of ionized air and ozone. When **S1** is closed, LED will visually signal when ionization is occurring.

[0088] Preferably operating parameters of unit **100** are set during manufacture and are generally not user-adjustable. For example, with respect to operating parameters, increasing the peak-to-peak output voltage and/or duty cycle in the high voltage pulses generated by unit **170** can increase the airflow rate, ion content, and ozone content. These parameters can be set by the user by adjusting switch **S2** as disclosed below. In the preferred embodiment, output flowrate is about 200 feet/minute, ion content is about 2,000,000/cc and ozone content is about 40 ppb (over ambient) to perhaps 2,000 ppb (over ambient). Decreasing the ratio of the radius of the nose of the second electrodes to the radius of the first electrode or decreasing the ratio of the cross-sectioned area of the second electrode to the first electrode below about 20:1 will decrease flow rate, as will decreasing the peak-to-peak voltage and/or duty cycle of the

high voltage pulses coupled between the first and second electrode arrays.

[0089] In practice, unit **100** is placed in a room and connected to an appropriate source of operating potential, typically **117** VAC. With **S1** energizing ionization unit **160**, systems **100** emits ionized air and preferably some ozone via outlet vents **106**. The airflow, coupled with the ions and ozone freshens the air in the room, and the ozone can beneficially destroy or at least diminish the undesired effects of certain odors, bacteria, germs, and the like. The airflow is indeed electro-kinetically produced, in that there are no intentionally moving parts within unit **100**. (Some mechanical vibration may occur within the electrodes.).

<u>Dual Ion Generating Unit Embodiment With Germicidal Lamp:</u>

<u>Figs. 14A-14B</u>

[0090] Figs. 14A-14B illustrate that the unit **200** may also include a germicidal lamp **290** to further reduce or kill bacteria within the airflow. The germicidal lamp **290** is preferably a UV-C lamp that emits viewable light and radiation (in combination referred to as radiation or light **280**) having wavelength of about 254 nm. This wavelength is effective in diminishing or destroying bacteria, germs, and viruses to which it is exposed. Lamps **290** are commercially available. For example, the lamp **290** may be a Phillips model TUO 25W/G25 T8, a 25 W tubular lamp measuring about 25 mm in diameter by about 43 cm in length. Another suitable lamp is the Phillips TUO 8WG8 T6, an 8 W lamp measuring about 15 mm in diameter by about 29 cm in length. Other lamps that emit the desired wavelength can instead be used.

[0091] As previously mentioned, one role of the housing **210** is to prevent an individual from viewing, by way of example, ultraviolet (UV) radiation generated by the germicidal lamp **290** disposed

within the housing **210**. Figs. 14A-14B illustrate preferred locations of the germicidal lamp **290** within the housing **210**. Figs. 14A-14B further show the spacial relationship between the germicidal lamp **290** and the electrode assembly **220**, and the germicidal lamp **290** and the inlet **250** and the outlet **260** and the inlet and outlet louvers **212**.

[0092] In a preferred embodiment, the inner surface **211** of the housing **210** diffuses or absorbs the UV radiation emitted from the lamp **290**. By way of example only, the inner surface **211** of the housing **210** can be formed with a non-smooth finish, or a non-radiation reflecting or radiation absorbing finish or color, to also prevent the UV radiation from exiting through either the inlet **250** or the outlet **260**.

[0093] As discussed above, the fins **212** covering the inlet **250** and the outlet **260** also limit any line of sight of the user into the housing **210**. The fins **212** covering the outlets are vertical. The fins **212** covering the inlets**204a, 204b** are horizontal. Preferably, the fins **212** covering the inlet and the outlet are all parallel to each other and are also parallel to the second collector electrode **242** (excluding any tail portion **246** of the second collector electrode) in order to streamline the airflow. Preferably, at least the outlet fins and the second collector electrodes **242** are parallel. Thus, it can also be observed that the fins **212** covering the inlets **204a**, **204b** are about parallel with the sides of the housing **210**. It is to be understood, however, that an embodiment of the invention also works if none of the fins and the electrodes are parallel. The depth D of each fin **212** is preferably deep enough to prevent an individual from directly viewing the portion of the interior wall **211** upon which UV radiation strikes. In a preferred embodiment, an individual cannot directly view the inner surface **211** by moving from side-to-side, while looking into either outlet vent **260a** or **206b**, or either inlet vent **204a** or **204b**. Looking between the fins **212** and into the housing **210** allows an individual to "see through" the device **200**. That is, a user can look into one of

the outlet vents **206a** and at the other outlet vent **206b**. It is to be understood that it is acceptable to see light or a glow coming from within housing **210** if the light has a non-UV wavelength. In general, an user viewing into the inlets **204a, 204b** or the outlets **206a, 206b** may be able to notice a light or glow emitted from within the housing **210**. In general, the radiation **280** reflected off the interior surface **211** of the housing **210**, has shifted from the UV spectrum. The wavelength of the radiation changes from the UV spectrum into an appropriate viewable spectrum. Thus, any light emitted from within the housing **210** is appropriate to view.

[0094] As also discussed above, the housing **210** is designed to optimize the reduction of microorganisms within the airflow. The efficacy of radiation **280** upon microorganisms depends upon the length of time such organisms are subjected to the radiation **280**. Thus, the lamp **290** is preferably located within the housing **210** where the airflow is the slowest. In preferred embodiments, the lamp **290** is disposed within the housing **210** along line A-A. Line A-A designates the largest width and cross-sectional area of the housing **210**, perpendicular to the airflow. The housing **210** creates a fixed volume for the air to pass through. In operation, air enters the inlets **204a** and **204b** which has a smaller width, and cross-sectional area, than along line A-A. Since the width and cross-sectional area of the housing at line A-A are larger than the width and cross-sectional area of the inlet **204a** or **204b**, the airflow will decelerate from the inlet to the line A-A. By placing the lamp **290** substantially along line A-A, the air will have the longest dwell time as it passes through the radiation **280** emitted by the lamp **290**. In other words, the microorganisms within the air will be subjected to the radiation **280** for the longest period possible by placing the lamp **290** along line A-A. It is, however, within the scope of the present invention to locate the lamp **290** anywhere within the housing **210**, preferably upstream of the electrode assembly **220**.

[0095] A radiation-shielding shell **270** substantially surrounds the lamp **290.** The lamp **290**, as shown in Figs. 14A-14C, is a circular tube parallel to the housing **210**. Thus, without the shell **270**, lamp radiation **280** would be emitted in all directions from the lamp **290**. The shell **270** mounts to secure the lamp **290** within the housing **210**. The interior surface **271** of the shell **270** can be blackened. The shell **270** has fins **272** that are spaced apart and substantially parallel to the lamp **290**. The fins **272** direct the radiation **280** toward the interior wall **211** away from the inlet **204a** or **204b**, or the outlet **206a** or **206b**. The shell **270** directs the radiation towards the fins **272** for irradiating the passing airflow. The shell **270** directs the radiation **280** emitted from the lamp **290** in a substantially perpendicular orientation, in a preferred embodiment, to the crossing airflow traveling through the housing **210**. This directing effect prevents the radiation **280** from being emitted directly towards the inlet **204a** or **204b** or the outlet **206a** or **206b**. In other embodiments the shell **270** and the fins **272** can have reflective surfaces if desired. In the embodiment shown in Fig. 14A, the lamp **290** is located along the side of the housing **210**. Thus, soon after the air passes through the inlet **204a** or **204b**, the air is immediately exposed to the radiation emitted by the lamp **290**.

[0096] Another preferred location of the lamp **290** along line A-A is shown in Fig. 14B. Two walls **274a, 274b** direct the radiation **280** away from the electrode assemblies **220**, the inlets **204a** and **204b**, and the outlets **206a** and **206b**. The wall **274a** is located between the lamp **290** and the electrode assembly **220a** and the outlet **206a**. The second wall **274b** is located between the lamp **290** and the electrode assembly **220b** and the outlet **206b**. Both walls **274a, 274b** prevent a user from directly looking through the outlets **206a** and **206b** and viewing the UV radiation emitted from the lamp **290**. To prevent the light emitted from the lamp **290** from shining directly at the inlets **204a** and **204b**, the walls **274a** and

274b form a cover over the top and bottom of the lamp **290**. Preferably, the first and second walls **274a**, **274b** are curved, with the convex surface facing the lamp **290**, in order to direct radiation from the lamp **290** outward toward the flow of air. It is within the scope of the present invention for the first and second walls **274a, 274b** to have other shapes such as, but not limited to, "V"-shaped and concave.

[0097] Fig. 14C illustrates the unit **200** having two germicidal lamps **290** within the housing **210**. In this embodiment, a first germicidal lamp **290a** is located between the third focus electrode **224** and the first electrode assembly **220a** and the outlet **206a**. A second germicidal lamp **290b** is located between the third focus electrode **206b**. Each germicidal lamp **290a** and **290b** has a shell **270** substantially surrounding it, similar to the embodiment previously shown in Fig. 14A. It is within the spirit and scope of the present invention to incorporate the walls **274a** and **274b** from Fig. 14B into this embodiment, and to use other configurations to prevent the light **280** from shining directly into the inlets or outlets.

[0098] Figs. 14A-14C illustrate embodiments of the electrode assembly **220** somewhat similar to those shown in Figs. 5G-5H. However, it is to be understood that any of the electrode assembly configurations depicted in Figs. 5A-13C may be used in the device **200** depicted in Figs. 14A-14C.

[0099] In Fig. 3D, the housing **210** has a removable side panel **207**, allowing a user to access and remove the germicidal lamp **290** from the housing **210** when the lamp **290** expires. The side panel **207** has locking tabs **226** located on each side, along the entire length of the panel **224**. The locking tabs **226**, as shown in Fig. 3D, are "L"-shaped. Each tab **226** extends away from the panel **207** inward towards the housing **210**, and then projects downward, parallel with the edge of the panel **207**. It is within the spirit and scope of the invention to have differently shaped tabs **226**. Each tab **226** individually and slidably interlocks with recesses **228** formed within the housing **210**. The side panel **207** also has a biased lever

(not shown) located at the bottom of the panel **207** that interlocks with the recess **230**. To remove the panel **207** from the housing **210**, the lever is urged away from the housing **210**, and the panel **207** is slid vertically upward until the tabs **226** disengage the recesses **228**. The panel **207** is then pulled away from the housing **210**. Removing the panel **207** exposes the lamp **290** for replacement.

[0100] The panel **207** also has a safety mechanism (not shown) to shut the device **200** off when the panel **207** is removed. The panel **207** has a rear projecting tab (not shown) that engages a safety interlock recess (not shown) when the panel **207** is secured to the housing **210**. By way of example only, the rear tab depresses a safety switch located within the recess when the front panel **207** is secured to the housing **210**. The device **200** will operate only when the rear tab in the panel **207** is fully inserted into the safety interlock recess. When the panel **207** is removed from the housing **210**, the rear projecting tab disengages from the recess and the power is cut-off to the entire device **200**. For example if a user removes the front panel **207** while the device **200** is running, and the germicidal lamp **290** is emitting UV radiation, the device **200** will turn off as soon as the rear projecting tab disengages from the recess. Preferably, the device **200** will turn off when the front panel **207** is removed only a very short distance (e.g., ¼") from the housing **210**.

[0101] Fig. 3E illustrates yet another embodiment of the housing **210**. In this embodiment, the germicidal lamp **290** can be removed from the housing **210** by lifting the germicidal lamp **290** vertically out of the housing **210**. Thus, the housing **210** does not need a removable side panel **202** to access the germicidal lamp **290**. Instead, a handle **225** is affixed to a lamp fix fixture that holds the germicidal lamp **290**. The handle **225** is located on the top surface **203** of the housing **210**, when the lamp **290** is within the housing **210** similar to the handle **212** for removing the second electrodes. To remove the lamp fixture

and lamp **290**, the handle **225** is pulled vertically out of the housing **210**. The lamp **290** is situated within the housing **210** in a similar manner to the second array of electrodes **240**. That is to say, that when the lamp **290** is pulled vertically out of the top surface **203** of the housing **210**, the electrical circuit that provides power to the lamp **290** is disconnected. As the handle **225** is lifted from the housing **210**, a cutoff switch will shut the entire device **200** off. This safety mechanism ensures that the device **200** will not operate without the lamp **290** placed securely in the housing **210**, preventing an individual from directly viewing the radiation emitted from the lamp **290**. Reinserting the lamp **290** into the housing **210** causes the lamp fixture to be re-engaged with the circuit contacts as is known in the art. In similar, but less convenient fashion, the lamp **290** is designed to be removed from the bottom of the housing **210**.

<u>Electrical Circuit for the Electro-Kinetic Device:</u>

[0102] Fig. 4B and 4C depict an electrical schematic that is switchable for use with a germicidal lamp system.

[0103] Figs. 4B-4C illustrate a preferred embodiment of an electrical block diagram for the electro-kinetic device **200** with enhanced anti-microorganism capability. Fig. 4A illustrates a preferred electrical block diagram of the germicidal lamp circuit **101**. The main components of the circuit **101** are an electromagnetic interference (EMI) filter **110**, an electronic ballast **112**, and a DC power supply **114**. The device **200** has an electrical power cord that plugs into a common electrical wall socket. The (EMI) filter **110** is placed across the incoming 110VAC line to reduce and/or eliminate high frequencies generated by the electronic ballast **112** and the DC Power Supply **114**. The electronic ballast **112** is electrically connected to the germicidal lamp **290** to regulate, or control, the flow of current through the lamp **290**.

Electrical components such as the EMI Filter **110** and electronic ballast **112** are well known in the art and do not require a further description. The DC Power Supply **114** receives the 110VAC and outputs 12VDC for the internal logic of the device **200**, and 160VDC for the primary side of the transformer **116** (see Fig. 4C).

[0104] As seen in Fig. 4C, a high voltage pulse generator **170** is coupled between the first electrode array **230** and the second electrode array **240**. The generator **170** receives low input voltage, e.g., 160VDC from DC power supply **114**, and generates high

voltage pulses of at least 5 KV peak-to-peak with a repetition rate of about 20 KHz. Preferably, the voltage doubler **118** outputs 9KV to the first array **230**, and 18KV to the second array **240**. It is within the scope of the present invention for the voltage doubler **118** to produce a greater or smaller voltage. The pulse train output preferably has a duty cycle of perhaps 10%, but may have other duty cycles, including a 100% duty cycle. The high voltage pulse generator **170** may be implemented in many ways, and typically will comprise a low voltage converter oscillator **124**, operating at perhaps 20 KHz frequency, that outputs low voltage pulses to an electronic switch. Such a switch is shown as an insulated gate bipolar transistor (IGBT) **126**. The IGBT **126**, or other appropriate switch, couples the low voltage pulses from the oscillator **124** to the input winding of a step-up transformer **116**. The secondary winding of the transformer **116** is coupled to the voltage doubler **118**, which outputs the high voltage pulses to the first and second array of electrodes **230, 240**. In general, the IGBT **126** operates as an electronic on/off switch. Such a transistor is well known in the art and does not require a further description.

[0105] The voltage doubler **118** preferably includes circuitry controlling the shape and/or duty cycle of the output voltage of the generator **170**. The voltage doubler **118** preferably also includes a pulse

mode component, controlled by the boost timer **128**, to temporarily provide a burst of increased output ozone.

[0106] The converter oscillator **124** receives electrical signals from the airflow modulating circuit **120**, the power setting circuit **122**, and the boost timer **128**. The airflow rate of the device **200** is primarily controlled by the airflow modulating circuit **120** and the power setting circuit **122**. The airflow modulating circuit **120** is a "micro-timing" gating circuit. The airflow modulating circuit **120** outputs an electrical signal that modulates between a "low" airflow signal and a "high" airflow signal. The airflow modulating circuit **120** continuously modulates between these two signals, preferably outputting the "high" airflow signal for 2.5 seconds, and then the "low" airflow signal for 5 seconds. By way of example only, the "high" airflow signal causes the voltage doubler **118** to provide 9KV to the first array **230**, while 18KV is provided to the second array **240**, and the "low" airflow signal causes the voltage doubler **118** to provide 6KV to the first array **230**, while 12KV is provided to the second array **240**. As will be described later, the voltage difference between the first and second array is proportional to the airflow rate of the device **200**. In general, a greater voltage differential is created between the first and second array by the "high" airflow signal. It is within the scope of the present invention for the airflow modulating circuit **120** to produce different voltage differentials between the first and second arrays. The various circuits and components comprising the high voltage pulse generator **170** can be fabricated on a printed circuit board mounted within housing **210**.

[0107] The power setting circuit **122** is a "macro-timing" circuit that can be set, by a control dial **214** (described hereinafter), to a LOW, MED, or HIGH setting. The three settings determine how long the signal generated by the airflow modulating circuit **120** will drive the oscillator **124**. When the control

dial **214** is set to HIGH, the electrical signal output from the airflow modulating circuit **120**, modulating between the high and low airflow signals, will continuously drive the connector oscillator **124**. When the control dial **214** is set to MED, the electrical signal output from the airflow modulating circuit **120** will cyclically drive the oscillator **124** for 25 seconds, and then drop to a zero or a lower voltage for 25 seconds. Thus, the airflow rate through the device **200** is slower when the dial **214** is set to MED than when the control dial **214** is set to HIGH. When the control dial **214** is set to LOW, the signal from the airflow modulating circuit **120** will cyclically drive the oscillator **124** for 25 seconds, and then drop to a zero or a lower voltage for 75 seconds. It is within the scope and spirit of the present invention for the HIGH, MED, and LOW settings to drive the oscillator **124** for longer or shorter periods of time.

[0108] The boost timer **128** sends a signal to the converter oscillator **124** when the boost button **216** is depressed. The boost timer **128** when activated, instructs the device **200** to run at a maximum airflow rate for a 5 minute period. This maximum airflow rate preferably creates an airflow velocity higher than that created when the control dial **214** is set to HIGH.

[0109] Fig. 4C further illustrates some preferred timing and maintenance features of the device **200**. The device **200** has a 2 week timer **130** and an arc sensing circuit **132** that either shuts the device **200** completely off, or provides a reminder to the user to clean the device **200**.

Electrode Assembly with First and Second Electrodes:

[0110] Having described various aspects of the invention in general, preferred embodiments of the electrode assembly **220** will now be described. The embodiments shown in Figs. 5A-13C only illustrate a single electrode assembly **220**. As previously mentioned, the unit **200** preferably includes two electrode

assemblies **220** within the housing **210**. Thus, a complete unit **200** will include a combination of any or more two electrode assemblies disclosed in Figs. 5A-13C.

Figs. 5A-5H

[0111] Figs. 5A-5H illustrate several configurations of the electrode assembly **220**. As shown in Fig. 5A, the output from high voltage pulse generator unit **170** is electronically connected to an electrode assembly **220** that comprises a first electrode array **230** and a second electrode array **240**. Again, instead of arrays, single electrodes or single conductive surfaces can be substituted for one or both array **230** and array **240**.

[0112] In a preferred embodiment, the positive output terminal of unit **170** is electrically connected to first electrode array **230**, and the negative output terminal is coupled to second electrode array **240**. It is believed that with this arrangement the net polarity of the emitted ions is positive, e.g., more positive ions than negative ions are emitted. This coupling polarity has been found to work well, including minimizing unwanted audible electrode vibration or hum. However, while generation of positive ions is conducive to a relatively silent airflow, from a health standpoint, it is desired that the output airflow be richer in negative ions, not positive ions. It is noted that in some embodiments, one port (preferably the negative port) of the high voltage pulse generator **170** can in fact be the ambient air. Thus, electrodes in the second array **240** need not be electrically connected to the high voltage pulse generator **170** using a wire. Nonetheless, there will be an "effective connection" between the second array electrodes **240** and one output port of the high voltage pulse generator **170**, in this instance, via ambient air. Alternatively, the negative output terminal of unit **170** can be connected to the first electrode array **230** and the position output terminal can be

connected to the second electrode array **240**.

[0113] With this arrangement an electrostatic flow of air is created, going from the first electrode array **230** towards the second electrode array **240**. (This flow is denoted "OUT" in the figures.) Accordingly, electrode assembly **220** is mounted within transporter system **100** or **200** such that second electrode array **240** is closer to the "OUT" vents and first electrode array **230** is closer to the "IN" vents.

[0114] When voltage or pulses from high voltage pulse generator **170** are electrically connected across first and second electrode arrays **230** and **240**, a plasma-like field is created surrounding electrodes **232** in first array **230**. This electric field ionizes the ambient air between the first and second electrode arrays and establishes an "OUT" airflow that moves towards the second array **240**. It is understood that the "IN" flow enters via vents **104**, or **204a** and **204b**, and that the "OUT" flow exits via vents **106**, or **206a** and **206b**.

[0115] Ozone and ions are generated simultaneously by the first array electrodes **232**, essentially as a function of the potential from generator **170** electrically connected to the first array of electrodes or conductive surfaces **230**. Ozone generation can be increased or decreased by increasing or decreasing the potential at the first array **230**. Electrically connecting an opposite polarity potential to the second array electrodes **242** essentially accelerates the motion of ions generated at the first array **230**, producing the airflow denoted as "OUT" in the figures. As the ions and ionized particles move toward the second array **240**, the ions and ionized particles push or move air molecules toward the second array **240**. The relative velocity of this motion may be increased, by way of example, by decreasing the potential at the second array **240** relative to the potential at the first array **230**.

[0116] For example, if +10 KV were applied to the first array electrode(s) **232**, and no potential

were applied to the second array electrode(s) **242**, a cloud of ions (whose net charge is positive) would form adjacent the first electrode array **230**. Further, the relatively high 10 KV potential would generate substantial ozone. By electrically connecting a relatively negative potential to the second array electrode(s) **242**, the velocity of the air mass moved by the net emitted ions increases.

[0117] On the other hand, if it were desired to maintain the same effective outflow (OUT) velocity, but to generate less ozone, the exemplary 10 KV potential could be divided between the electrode arrays. For example, generator **170** could provide +4 KV (or some other fraction) to the first array electrodes **232** and -6 KV (or some other fraction) to the second array electrodes **242**. In this example, it is understood that the +4 KV and the -6 KV are measured relative to ground. Understandably it is desired that the unit **100** or **200** operates to output appropriate amounts of ozone. Accordingly, the high voltage is preferably fractionalized with about +4 KV applied to the first array electrodes **232** and about -6 KV applied to the second array electrodes **242**.

[0118] In the embodiments of Figs. 5A and 5B, electrode assembly **220** comprises a first array **230** of wire-shaped electrodes **232**, and a second array **240** of generally "U"-shaped electrodes **242**. In preferred embodiments, the number N1 of electrodes comprising the first array can preferably differ by one relative to the number N2 of electrodes comprising the second array **240**. In many of the embodiments shown, N2>N1. However, if desired, additional first electrodes **232** could be added at the outer ends of array **230** such that N1>N2, e.g., five first electrodes **232** compared to four second electrodes **242**.

[0119] As previously indicated, first or emitter electrodes **232** are preferably lengths of tungsten wire, whereas electrodes **242** are formed from sheet metal, preferably stainless steel, although brass or other sheet metal could be used. The sheet metal is readily configured to define side regions **244** and

bulbous nose region **246**, forming the hollow, elongated "U"-shaped electrodes **242**. While Fig. 5A depicts four electrodes **242** in second array **240** and three electrodes **232** in first array **230**, as noted previously, other numbers of electrodes in each array could be used, preferably retaining a symmetrically staggered configuration as shown. It is seen in Fig. 5A that while particulate matter **60** is present in the incoming (IN) air, the outflow (OUT) air is substantially devoid of particulate matter, which adheres to the preferably large surface area provided by the side regions **244** of the second array electrodes **242**.

[0120] Fig. 5B illustrates that the spaced-apart configuration between the first and second arrays **230, 240** is staggered. Preferably, each first array electrode **232** is substantially equidistant from two second array electrodes **242**. This symmetrical staggering has been found to be an efficient electrode placement. Preferably, in this embodiment, the staggering geometry is symmetrical in that adjacent electrodes **232** or adjacent electrodes **242** are spaced-apart a constant distance, Y1 and Y2 respectively. However, a non-symmetrical configuration could also be used. Also, it is understood that the number of electrodes **232** and **242** may differ from what is shown.

[0121] In the embodiment of Figs. 5A and 5B, typically dimensions are as follows: diameter of electrodes **232**, R1, is about 0.08 mm, distances Y1 and Y2 are each about 16 mm, distance X1 is about 16 mm, distance L is about 20 mm, and electrode heights Z1 and Z2 are each about 1 m. The width W of electrodes **242** is preferably about 4 mm, and the thickness of the material from which electrodes **242** are formed is about 0.5 mm. Of course other dimensions and shapes could be used. For example, preferred dimensions for distance X1 may vary between 12-30mm, and the distance Y2 may vary between 15-30mm. It is preferred that electrodes **232** have a small diameter. A wire having a small diameter, such as R1, generates a high voltage field and has a high emissivity. Both characteristics are beneficial for

generating ions. At the same time, it is desired that electrodes **232** (as well as electrodes **242**) be sufficiently robust to withstand occasional cleaning.

[0122] Electrodes **232** in first array **230** are electronically connected to a first (preferably positive) output port of high voltage pulse generator **170** by a conductor **234**. Electrodes **242** in second array **240** are electrically connected to a second (preferably negative) output port of high voltage generator **170** by a conductor **249**. The electrodes may be electrically connected to the conductors **234** or **249** at various locations. By way of example only, Fig. 5B depicts conductor **249** making connection with some electrodes **242** internal to bulbous end **246**, while other electrodes **242** make electrical connection to conductor **249** elsewhere on the electrode **242**. Electrical connection to the various electrodes **242** could also be made on the electrode external surface, provided no substantial impairment of the outflow airstream results; however it has been found to be preferable that the connection is internal.

[0123] In this and the other embodiments to be described herein, ionization appears to occur at the electrodes **232** in the first electrode array **230**, with ozone production occurring as a function of high voltage arcing. For example, increasing the peak-to-peak voltage amplitude and/or duty cycle of the pulses from the high voltage pulse generator **170** can increase ozone content in the output flow of ionized air. If desired, user-control **S2** or dial **214** can be used to somewhat vary ozone content by varying amplitude and/or duty cycle. Specific circuitry for achieving such control is known in the art and need not be described in detail herein.

[0124] Note the inclusion in Figs. 5A and 5B of at least one output controlling electrode **243**, preferably electrically connected to the same potential as the second array electrodes **242**. Electrode **243** preferably defines a pointed shape in side profile, e.g., a triangle. The sharp point on electrodes **243** causes

generation of substantial negative ions (since the electrode is electrically connected to a relatively negative high potential). These negative ions neutralize excess positive ions otherwise present in the output airflow, such that the "OUT" flow has a net negative charge. Electrodes **243** is preferably stainless steel, copper, or other conductor material, and is perhaps 20 mm high and about 12 mm wide at the base. The inclusion of one electrode **243** has been found sufficient to provide a sufficient number of output negative ions, but more such electrodes may be included.

[0125] In the embodiments of Figs. 5A, 5B and 5C, each "U"-shaped electrode **242** has two trailing surface or sides **244** that promote efficient kinetic transport of the outflow of ionized air and ozone. For the embodiment of Fig. 5C, there is the inclusion on at least one portion of a trailing edge of a pointed electrode region **243'**. Electrode region **243'** helps promote output of negative ions, in the same fashion that was previously described with respect to electrodes **243**, as shown in Figs. 5A and 5B.

[0126] In Fig. 5C and the figures to follow, the particulate matter is omitted for ease of illustration. However, from what was shown in Figs. 5A-5B, particulate matter will be present in the incoming air, and will be substantially absent from the outgoing air. As has been described, particulate matter **60** typically will be electrostatically precipitated upon the surface area of electrodes **242**.

[0127] As discussed above and as depicted by Fig. 5C, it is relatively unimportant where on an electrode array electrical connection is made. Thus, first array electrodes **232** are shown electrically connected together at their bottom regions by conductor **234**, whereas second array electrodes **242** are shown electrically connected together in their middle regions by the conductor **249**. Both arrays may be connected together in more than one region, e.g., at the top and at the bottom. It is preferred that the wire or strips or other inter-connecting mechanisms be at the top, bottom, or periphery of the second array

electrodes **242**, so as to minimize obstructing stream air movement through the housing **210**.

[0128] It is noted that the embodiments of Figs. 5C and 5D depict somewhat truncated versions of the second electrodes **242**. Whereas dimension L in the embodiment of Figs. 5A and 5B was about 20 mm, in Figs. 5C and 5D, L has been shortened to about 8 mm. Other dimensions in Fig. 5C preferably are similar to those stated for Figs. 5A and 5B. It will be appreciated that the configuration of second electrode array **240** in Fig. 5C can be more robust than the configuration of Figs. 5A and 5B, by virtue of the shorter trailing edge geometry. As noted earlier, a symmetrical staggered geometry for the first and second electrode arrays is preferred for the configuration of Fig. 5C.

[0129] In the embodiment of Fig. 5D, the outermost second electrodes, denoted **242-1** and **242-4**, have substantially no outermost trailing edges. Dimension L in Fig. 5D is preferably about 3 mm, and other dimensions may be as stated for the configuration of Figs. 5A and 5B. Again, the ratio of the radius or surface areas between the first electrode **232** and the second electrodes **242** for the embodiment of Fig. 5D preferably exceeds about 20:1.

[0130] Figs. 5E and 5F depict another embodiment of electrode assembly **220**, in which the first electrode array **230** comprises a single wire electrode **232**, and the second electrode array **240** comprises a single pair of curved "L"-shaped electrodes **242**, in cross-section. Typical dimensions, where different than what has been stated for earlier-described embodiments, are $X1 \approx 12$ mm, $Y2 \approx 5$ mm, and $L1 \approx 3$ mm. The effective surface area or radius ratio is again greater than about 20:1. The fewer electrodes comprising assembly **220** in Figs. 5E and 5F promote economy of construction, and ease of cleaning, although more than one electrode **232**, and more than two electrodes **242** could of course be employed. This particular embodiment incorporates the staggered symmetry described earlier, in which electrode **232**

is equidistant from two electrodes **242**. Other geometric arrangements, which may not be equidistant, are within the spirit and scope of the invention.

[0131] Figs. 5G-5H illustrate that the second electrodes **242** may have angled, Z-shaped or other corrugated extensions or sections **294**. These electrodes can also be hollow. Preferably, the tail extension **294** is a non-linear configuration, having an effective width W' greater than the width W (see Fig. 5B) of the second electrode **242**. The extensions **294** enhance the particle capture efficiency of the electrode assembly **220**. Larger airborne particles (e.g., one micron and larger) tend to have their own significant forward momentum in the air stream. A "U"-shaped second electrode **242** without an angled blade extension **294**, as shown in Fig. 5A, might allow a larger particle to pass through the electrode assembly **220** uncaptured. The momentum of the particle may prevent it from contacting the trailing edges **244** of the second electrode **242**. The increased width W' of the angled extension **246** is intended to capture the larger particles. For example, if the larger particle passes by the trailing side **244** of the second electrode **242** uncaptured, but the particle is within W' of the trailing sides **244**, the particle will be captured by the extension **294**. It is within the spirit and scope of the invention for the extension **294** to comprise other non-linear shapes and configurations such as, but not limited to, a "U"-shape, an "L"-shape, a "Z"-shape, or a shape with a first upstream portion and a second downstream portion positioned at an angle to the upstream portion, and a shape with a tail section that is wider in the downstream portion than the upstream, leading, or nose portion.

[0132] In Fig. 5G all tail sections **294** are parallel and point in the same direction. Alternatively, the tail sections **256** can be configured to diverge in order to form a "V" or "Y" configured adjacent to the outlet vents. Thus, in Fig. 5H the upper two tail sections **294** are configured to point upwardly on the page

while the lower two tail sections remain pointing downward.

[0133] Figs. 5G-5H also show that in another preferred embodiment the second electrode can be arranged in a non-equidistant arrangement relative to the first electrodes. Thus, in Figs. 5G and 5H, the middle two second electrodes **243-2** and **242-3** are recessed back further from the first electrode array **230** than the outer electrode **242-1** and **242-4**. This arrangement can give better airflow through the ion generating unit **220**. It is within the spirit and scope of the invention for all the embodiments shown in Figs. 5A-13C to incorporate this feature.

[0134] Figs. 5I-5J illustrate a second array of electrodes **240** where each second electrode **242** has a tail section **276** that is wider than the nose **246**. The trailing sides **244** angle outward from the nose **246** as the sides **244** extend downstream. Overall, the electrode **242** is teardrop or "V" shaped with the nose **246** located closer to the first array of electrodes **230**. This embodiment traps or collects particles in a similar fashion as the electrodes shown in Figs. 5G-5H. In general, the larger width of the tail section **276** will collect particles within the airflow that may go uncollected by a thinner second electrode **242** (see, for example, Fig. 5A). As is evident from the figures the nose is rounded and substantially smaller than the rounded bulbous tail of the second electrode **242**. The nose is rounded so that it does not become an emitter as are the first electrodes. Further the nose has a radius that is larger than the radius of the first electrode, preferably fifteen times larger.

[0135] As shown in Figs. 5I and 5J, the second electrode **242** is hollow. It is within the scope and spirit of the invention for the electrode **242** to be a solid object.

[0136] As shown in Fig. 5J, the tail section **296** must not be so wide that the airflow passing between the second electrodes **242** is restricted and impair the airflow exiting the unit **100** or **200**.

Accordingly, and in a preferred embodiment, the distance between second electrodes, shown as Y2, is slightly larger in this embodiment.

Electrode Assembly With an Upstream Focus Electrode:

Figs. 6A-6B

[0137] The embodiments illustrated in Figs. 6A-6B are somewhat similar to the previously described embodiments in Figs. 5A-5B. The electrode assembly **220** includes a first array of electrodes **230** and a second array of electrodes **240**. Again, for this and the other embodiments, the term "array of electrodes" may refer to a single electrode or a plurality of electrodes. Preferably, the number of electrodes **232** in the first array of electrodes **230** will differ by one relative to the number of electrodes **242** in the second array of electrodes **240**. The distances L, X1, Y1, Y2, Z1 and Z2 for this embodiment are similar to those previously described in Fig. 5A.

[0138] As shown in Fig. 6A, the electrode assembly **220** preferably adds a third, or leading, or focus, or directional electrode **224a, 224b, 224c** (generally referred to as "electrode **224**") upstream of each first electrode **232-1, 232-2, 232-3**. The focus electrode **224** produces an enhanced airflow velocity exiting the devices **100** or **200.** In general, the third focus electrode **224** directs the airflow, and ions generated by the first electrode **232,** towards the second electrodes **242**. Each third focus electrode **224** is a distance X2 upstream from at least one of the first electrodes **232**. The distance X2 is preferably 5-6 mm, or four to five diameters of the focus electrode **224**. However, the third focus electrode **224** may be further from, or closer to, the first electrode **232**.

[0139] The third focus electrode **224** illustrated in Fig. 6A is a rod-shaped electrode. The third

focus electrode **224** may also comprise other shapes that preferably do not contain any sharp edges. The third focus electrode **224** is preferably manufactured from material that will not erode or oxidize, such as stainless steel. The diameter of the third focus electrode **224**, in a preferred embodiment, is at least fifteen times greater than the diameter of the first electrode **232**. However, the diameter of the third focus electrode **224** may be larger or smaller. The diameter of the third focus electrode **224** is preferably large enough so that third focus electrode **224** does not function as an ion emitting surface when electrically connected to the high voltage generator **170**. The maximum diameter of the third focus electrode **224** is somewhat constrained. As the diameter increases, the third focus electrode **224** will begin to noticeably impair the airflow rate of the units **100** or **200**. Therefore, the diameter of the third electrode **224** is balanced between the need to form a non-ion emitting surface and airflow properties of the unit **100** or **200**.

[0140] In a preferred embodiment, each third focus electrodes **224** is electrically connected to the first array **230** and the high voltage generator **170** by the conductor **234**. As shown in Fig. 6A, the third focus electrodes **224** are electrically connected to the same positive outlet of the high voltage generator **170** as the first array **230**. Accordingly, the first electrode **232** and the third focus electrode **224** generate a positive electrical field. Since the electrical fields generated by the third focus electrode **224** and the first electrode **232** are both positive, the positive field generated by the third focus electrode **224** will push, or repel, or direct, the positive field generated by the first electrode **232** towards the second array **240**. For example, the positive field generated by the third focus electrode **224a** will push, or repel, or direct, the positive field generated by the first electrode **232-1** towards the second array **240**. In general, the third focus electrode **224** shapes the electrical field generated by each electrode **232** in the first array **230**. This shaping effect is believed to decrease the amount of ozone generated by the electrode assembly **220** and

increases the airflow of the units **100** and **200**.

[0141] The particles within the airflow are positively charged by the ions generated by the first electrode **232**. As previously mentioned, the positively charged particles are collected by the negatively charged second electrodes **242**. The third focus electrode **224** also directs the airflow towards the second electrodes **242** by guiding the charged particles towards the trailing sides **244** of each second electrode **242**. It is believed that the airflow will travel around the third focus electrode **224**, partially guiding the airflow towards the trailing sides **244**, improving the collection rate of the electrode assembly **220**.

[0142] The third focus electrode **224** may be located at various positions upstream of each first electrode **232**. By way of example only, a third focus electrode **224b** is located directly upstream of the first electrode **232-2** so that the center of the third focus electrode **224b** is in-line and symmetrically aligned with the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrode **242-2** and the second electrode **242-3**.

[0143] Alternatively, a third focus electrode **224** may also be located at an angle relative to the first electrode **232**. For example, a third focus electrode **224a** may be located upstream of the first electrode **232-1** along a line extending from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**, as shown by extension line A. The third focus electrode **224a** is in-line and symmetrically aligned with the first electrode **232-1** along extension line A. Similarly, the third electrode **224c** is located upstream to the first electrode **232-3** along a line extending from the middle of the nose **246** of the second electrode **242-3** through the first electrode **232-3**, as shown by extension line C. The third focus electrode **224c** is in-line and symmetrically aligned with the first electrode **232-3** along extension line C. It is within the scope of the present invention for the electrode assembly **220** to

include third focus electrodes **224** that are both directly upstream and at an angle to the first electrodes **232**, as depicted in Fig. 6A. Thus, the focus electrodes **224** fan out in relation to the first array of electrodes **230**.

[0144] Fig. 6B illustrates that an electrode assembly **220** may contain multiple third focus electrodes **224** upstream of each first electrode **232**. By way of example only, the third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1**, as shown by extension line A. In a preferred embodiment, only the third focus electrodes **224a1**, **224b1**, **224c1** are electrically connected to the high voltage generator **170** by conductor **234**. Accordingly, not all of the third electrodes **224** are at the same operating potential. In the embodiment shown in Fig. 6B, the third focus electrodes **224a1**, **224b1**, **224c1** are at the same electrical potential as the first electrodes **232**, while the third focus electrodes **224a2**, **224b2**, **224c2** are floating. Alternatively, the third focus electrodes **224a2**, **224b2** and **224c2** may be electrically connected to the high voltage generator **170** by the conductor **234**.

[0145] Fig. 6B illustrates that each second electrode **242** may also have a protective end **241**. In the previous embodiments, each "U"-shaped second electrode **242** has an open end. Typically, the end of each trailing side or side wall **244** contains sharp edges. The gap between the trailing sides or side walls **244**, and the sharp edges at the end of the trailing sides or side walls **244**, generate unwanted eddy currents. The eddy currents create a "backdraft," or airflow traveling from the outlet towards the inlet, which slow down the airflow rate of the units **100** or **200**.

[0146] In a preferred embodiment, the protective end **241** is created by shaping, or rolling, the trailing sides or side walls **244** inward and pressing them together, forming a rounded trailing end with no gap between the trailing sides or side walls of each second electrode **242**. Accordingly, the side walls have

outer surfaces, and the outer surface of end of the side walls are bent back inwards towards the nose **246**, adjacent to the trailing ends of the side walls so that the outer surface of the side walls are adjacent to, or face, or touch each other. Preferably, a smooth trailing edge is integrally formed on the second electrode **242**. If desired, it is within the scope of the invention to spot weld the rounded ends together along the length of the second electrode **242**. It is also within the scope of the present invention to form the protective end **241** by other methods such as, but not limited to, placing a strap of plastic across each end of the trailing sides **244** for the full length of the second electrode **242**. The rounded or capped end is an improvement over the previous electrodes **242** without a protective end **241**. Eliminating the gap between the trailing sides **244** reduces or eliminates the eddy currents typically generated by a second electrode **242** with an open end. The rounded protective end **241** also provides a smooth surface for purpose of cleaning the second electrode. Accordingly, in this embodiment the collector electrode **242** is a one-piece, integrally formed, electrode with a protection end **241**.

Figs. 7A-7D

[0147] Fig. 7A illustrates an electrode assembly **220** including a first array of electrodes **230** having three wire-shaped first electrodes **232-1, 232-2, 232-3** (generally referred to as "electrode **232**"), and a second array of electrodes **240** having four "U"-shaped second electrodes **242-1, 242-2, 242-3, 242-4** (generally referred to as "electrode **242**"). Each first electrode **232** is electrically connected to the high voltage generator **170** at the bottom region, whereas each second electrode **242** is electrically connected to the high-voltage generator **170** in the middle to illustrate that the first and second electrodes **232, 242** can be electrically connected in a variety of locations.

[0148] The second electrode **242** in Fig. 7A is a similar version of the second electrode **242** shown in Fig. 5C. The distance L has been shortened to about 8mm, while the other dimensions X1, Y1, Y2, Z1, Z2 are similar to those shown in Fig. 5A.

[0149] A third leading, or focus, electrode **224** is located upstream of each first electrode **232**. The innermost third focus electrode **224b** is located directly upstream of the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrodes **242-2, 242-3**. The third focus electrodes **224a, 224c** are at an angle with respect to the first electrodes **232-1, 232-3**. For example, the third focus electrode **224a** is upstream to the first electrode **232-1** along a line extending from the middle of the nose **246** of the second electrode **242-2** extending through the center of the first electrode **232-1**, as shown by extension line A. The third electrode **224c** is located upstream of the first electrode **232-3** along a line extending from the center of the nose **246** of the second electrode **242-3** through the center of the first electrode **232-3**, as shown by extension line C. Accordingly, and preferably, the focus electrodes **242** fan out in relation to the first electrodes **232** as an aid for directing the flow of ions and charged particles. Fig. 7B illustrates that the third focus electrodes **224** may also be electrically connected to the high voltage generator **170** by conductor **234**.

[0150] Fig. 7C illustrates that a pair of third focus electrodes **224** may be located upstream of each first electrode **232**. Preferably, the multiple third focus electrodes **224** are in-line and symmetrically aligned with each other. For example, the third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1**, along extension line A. As previously mentioned, preferably only third focus electrodes **224a1, 224b1, 224c1** are electrically connected to the high voltage generator **170** by conductor **234**. It is also within the scope of the present invention to have none or all of the third focus electrodes **224**

electrically connected to the high voltage generator **170**.

[0151] Fig. 7D illustrates third focus electrodes **224** added to the electrode assembly **220** shown in Fig. 5D. Preferably, a third focus electrode **224** is located upstream of each first electrode **232**. For example, the third focus electrode **224b** is in-line and symmetrically aligned with the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrodes **242-2**, **242-3**. The third focus electrode **224a** is in-line and symmetrically aligned with the first electrode **232-1**, as shown by extension line A. Similarly, the third electrode **224c** is in-line and symmetrically aligned with the first electrode **232-3**, as shown by extension line C. Extension lines A-C extend from the middle of the nose **246** of the "U"-shaped second electrodes **242-2, 242-3** through the first electrodes **232-1, 232-3,** respectively. In a preferred embodiment, the third electrodes **224a, 224b, 224c** are electrically connected to the high voltage generator **170** by the conductor **234**. This embodiment may also include a pair of third focus electrodes **224** upstream of each first electrode **232**, as is depicted in Fig. 7C.

<u>Figs. 8A-8C</u>

[0152] Figs. 8A-8C illustrate that the electrode assembly **220** shown in Fig. 5E may include a third focus electrode **224** upstream of the first array of electrodes **230**. Preferably, the center of the third focus electrode **224** is in-line and symmetrically aligned with the center of the first electrode **232**, as shown by extension line B. Extension line B is located midway between the second electrodes **242**. The distances X1, X2, Y1, Y2, Z1 and Z2 are similar to the embodiments previously described. The first electrode **232** and the second electrode **242** may be electrically connected to the high voltage generator **170** by conductor **234, 249** respectively. It is within the scope of the present invention to connect the first and second

electrodes to opposite ends of the high voltage generator **170** (e.g., the first electrode **232** may be negatively charged and the second electrode **242** may be positively charged). In a preferred embodiment the third focus electrode **224** is also electrically connected to the high voltage generator **170**.

[0153] Fig. 8B illustrates that a pair of third focus electrodes **224a, 224b** may be located upstream of the first electrode **232**. The third focus electrodes **224a, 224b** are in-line and symmetrically aligned with the first electrode **232**, as shown by extension line B. Extension line B is located midway between the second electrodes **242**. Preferably, the third focus electrode **224b** is upstream of third focus electrode **224a** a distance equal to the diameter of a third focus electrode **224**. In a preferred embodiment, only the third focus electrode **224a** is electrically connected to the high voltage generator **170**. It is within the scope of the present invention to electrically connect both third focus electrodes **224a, 224b** to the high voltage generator **170**.

[0154] Fig. 8C illustrates that each third focus electrode **224** may be located at an angle with respect to the first electrode **232**. Similar to the previous embodiments, the third focus electrode **224a1** and **224b1** is located a distance X2 upstream from the first electrode **232**. By way of example only, the third focus electrodes **224a1, 224a2** are located along a line extending from the middle of the second electrode **242-2** through the center of the first electrode **232**, as shown by extension line A. The third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1** along extension line A. Similarly, the third focus electrodes **224b1, 224b2** are along a line extending from the middle of the second electrode **242-1** through the middle of the first electrode **232**, as shown by extension line B. The third focus electrode **224b2** is in line and symmetrically aligned with the third focus electrode **224b1** along extension line B. The third focus electrodes **224** are fanned out and form a "V" pattern upstream of

first electrode **232**. In a preferred embodiment, only the third focus electrodes **224a1** and **224b1** are electrically connected to the high voltage generator **170** by conductor **234**. It is within the scope of the invention to electrically connect the third focus electrodes **224a** and **224b2** to the high voltage generator **170**.

Figs. 9A-9C

[0155] The previously described embodiments of the electrode assembly **220** disclose a rod-shaped third focus electrode **224** upstream of each first electrode **232**. Fig. 9A illustrates an alternative configuration for the third focus electrode **224**. By way of example only, the electrode assembly **220** may include a "U"-shaped or possibly "C"-shaped third focus electrode **224** upstream of each first electrode **232**. Further, the third focus electrode **224** can have other curved configurations such as, but not limited to, circular-shaped, elliptical-shaped, parabolically-shaped, and other concave shapes facing the first electrode **232**. In a preferred embodiment, the third focus electrode **224** has holes **225** extending through, forming a perforated surface to minimize the resistance of the third focus electrode **224** on the airflow rate. Further in other embodiments the "U"-shaped third focus electrode **224** can be made of a screen or a mesh.

[0156] In a preferred embodiment, the third focus electrode **224** is electrically connected to the high voltage generator **170** by conductor **234**. The third focus electrode **224** in Fig. 9A is preferably not an ion emitting surface. Similar to previous embodiments, the third focus electrode **224** generates a positive electric field and pushes or repels the electric field generated by the first electrode **232** towards the second array **240**. Fig. 9B illustrates that a perforated "U"-shaped or "C"-shaped third focus electrode **224** can

be incorporated into the electrode assembly **220** shown in Fig. 5A.

[0157] Fig. 9C illustrates third focus electrodes **224** similar to those depicted in Fig. 9B, except that the third focus electrodes **224** are rotated by 180° to preset a convex surface facing to the first electrodes **232** in order to focus and direct the field of ions and airflow from the first electrode **232** toward the second electrode **242**. These third focus electrodes **224** shown in Figs. 9A-9C are located along extension lines A, B, C similar to previously described embodiments.

Figs. 10A-10C

[0158] Fig. 10A illustrates a pin-ring configuration of the electrode assembly **220**. The electrode assembly **220** contains a cone-shaped or triangular-shaped first electrode **232**, a ring-shaped second electrode **242** downstream of the first electrode **232**, and a third focus electrode **250** upstream of the first electrode **232**. In a preferred embodiment, the third focus electrode **250** is electrically connected to the high voltage generator **170**. Alternatively, the third focus electrode **250** can have a floating potential. As indicated by phantom elements **232'**, **242'**, the electrode assembly **220** can comprise a plurality of such pin-like and ring-like elements. The plurality of pin-ring configurations as depicted in Fig. 10A can be positioned one above the other along the elongated housing of the invention. Such a plurality of pin-ring configurations can of course operate in another embodiment without the third focus electrode **250**. It is understood that this plurality of pin-ring configurations can be upstanding and elongated along the elongated direction of said housing and can replace the first and second electrodes shown, for example, in Fig. 2B, and be removable much as the second electrode in Fig 2B is removable. Preferably, the first electrode **232** is tungsten, and the second electrode **242** is stainless steel. Typical dimensions for the embodiment of Fig.

10A are L1 ≈ 10 millimeters, X1 ≈ 9.5 millimeters, T ≈ 0.5 millimeters and the diameter of the opening 246 ≈ 12millimeters.

[0159] The electrical properties and characteristics of the third focus electrode **250** is similar to the third focus electrode **224** described in previous embodiments. In contrast to the rod-shaped physical characteristic of the previous embodiments, the shape the third focus electrode **250** is a disc, with the concave surface preferably facing toward the second electrode **242**. The third focus electrode **250** preferably has holes extending therethrough to minimize the disruption in airflow. It is within the scope of the present invention for the third focus electrode **250** to comprise other shapes such as, but not limited to, a convex disc, a parabolic disc, a spherical disc, or other convex or concave shapes, or a rectangle, or other planar surface and be within the spirit and scope of the invention. The diameter of the third focus electrode **250** is preferably at least fifteen times greater than the diameter of the first electrode **232**.

[0160] The second electrode **242** has an opening **246**. The opening **246** is preferably circular in this embodiment. It is within the scope of the present invention that the opening **246** can comprise other shapes such as, but not limited to, rectangular, hexagonal or octagonal. The second electrode **242** has a collar **247** (see Fig. 10B) surrounding the opening **246**. The collar **247** attracts the dust contained within the airstream passing through the opening **246**. As a result, the airstream emitted by the electrode assembly **220** has a reduced dust content.

[0161] Other similar pin-ring embodiments are shown in Figs. 10B-10C. For example, the first electrode **232** may comprise a rod-shaped electrode having a tapered end. In Fig. 10B, a detailed cross-sectional view of the central portion of the second electrode **242** in Fig. 10A is shown. Preferably, the collar **247** is positioned in relation to the first electrode **232**, such that the ionization paths from the distal

tip of the first electrode **232** to the collar **247** have substantially equal path lengths. Thus, while the distal tip (or emitting tip) of the first electrode **232** is advantageously small to concentrate the electric field, the adjacent regions of the second electrode **242** preferably provide many equidistant inter-electrode paths. The lines drawn in phantom in Figs. 10B and 10C depict theoretical electric force field lines emanating from the first electrode **232** and terminating on the curved surface of the second electrode **242**. Preferably, the bulk of the field emanates within about 45 degrees of coaxial axis between the first electrode **232** and the second electrode **242**.

[0162] In Fig. 10C, one or more first electrodes **232** are replaced by a conductive block **232"** of carbon fibers, the block having a distal surface in which projecting fibers **233-1**,...**233-N** take on the appearance of a "bed of nails." The projecting fibers can each act as an emitter electrode and provide a plurality of emitting surfaces. Over a period of time, some or all of the electrodes will literally be consumed, where upon the block **232"** may be replaced. Materials other than graphite may be used for block **232"** providing that the material has a surface with projecting conductive fibers such as **233-N**.

<u>Electrode Assembly With a Downstream Trailing Electrode:</u>

<u>Figs. 11A-11D</u>

[0163] Figs. 11A-11C illustrate an electrode assembly **220** having an array of trailing electrodes **245** added to an electrode assembly **220** similar to that shown in Fig. 8A. It is understood that an alternative embodiment similar to Fig. 11A can include a trailing electrode or electrodes **245** without any focus electrodes **224** and be within the spirit and scope of the inventions. Referring now to Figs. 11A-11B, each trailing electrode **245** is located downstream of the second array of electrodes **240**. Preferably, the

trailing electrodes **245** are located downstream from the second electrodes **242** by at least three times the radius R2 (see Fig. 11B). Further, the trailing electrodes **245** are preferably directly downstream of each second electrode **242** so as not to interfere with the flow of air. Also, the trailing electrode **245** is aerodynamically smooth, for example, circular, elliptical, or teardrops shaped in cross-section so as not to unduly interfere with the smoothness of the airflow thereby. In a preferred embodiment, the trailing electrodes **245** are electrically connected to the same outlet of the high voltage generator **170** as the second array of electrodes **240**. As shown in Fig. 11A, the second electrodes **242** and the trailing electrodes **245** have a negative electrical charge. This arrangement can introduce more negative charges into the air stream. Alternatively, the trailing electrodes **245** may have a floating potential and not be electrically connected to the high voltage generator **170**. The trailing electrode can also be grounded in other embodiments. Further, alternatively as shown in Fig. 11D, the trailing electrode **245** can be formed with the second electrode out of a sheet of metal formed in the shape of the second electrode and then extending to the position of the trailing electrode and formed as a hollow trailing electrode with a peripheral wall that is about the shape of the outer surface of the trailing electrode **245** depicted in Fig. 11C.

[0164] When the trailing electrodes **245** are electrically connected to the high voltage generator **170**, the positively charged particles within the airflow are also attracted to and collect on, the trailing electrodes **245**. In an electrode assembly with no trailing electrode **245**, most of the particles will collect on the surface area of the second electrodes **242**. However, some particles will pass through the unit **200** without being collected by the second electrodes **242**. The trailing electrodes **245** serve as a second surface area to collect the positively charged particles. The trailing electrodes **245** may also deflect charged particles toward the second electrodes **242**.

[0165] The trailing electrodes **245** preferably also emit a small amount of negative ions into the airflow. These negative ions will neutralize the positive ions emitted by the first electrodes **232**. If the positive ions emitted by the first electrodes **232** are not neutralized before the airflow reaches the outlet **260**, the outlet fins **212** may become electrically charged and particles within the airflow may tend to stick to the fins **212**. If this occurs, the amount of particles collected by the fins **212** will eventually block or minimize the airflow exiting the unit **100** or **200**.

[0166] Fig. 11C illustrates another embodiment of the electrode assembly **200**, with trailing electrodes **245** added to an embodiment similar to that shown in Fig. 8C. The trailing electrodes **245** are located downstream of the second array **240** similar to the previously described embodiments above. It is within the scope of the present invention to electrically connect the trailing electrodes **245** to the high voltage generator **170**. As shown in Fig. 11C, all of the third focus electrodes **224** are electrically connected to the high voltage generator **170**. In a preferred embodiment, only the third focus electrodes **224a1, 224b1** are electrically connected to the high voltage generator **170**, and the third focus electrodes **224a2, 224b2** have a floating potential.

<u>Electrode Assemblies With Various Combinations of Focus Electrodes, Trailing Electrodes and Enhanced Second Electrodes With Protective Ends:</u>

<u>Figs. 12A-12D</u>

[0167] Fig. 12A illustrates an electrode assembly **220** that includes a first array of electrodes **230** having two wire-shaped electrodes **232-1, 232-2** (generally referred to as "electrode **232**") and a second array of electrodes **240** having three "U"-shaped electrodes **242-1, 242-2, 242-3** (generally referred to

as "electrode **242**"). This configuration is in contrast to, for example, the configurations of Fig. 10A, wherein there are three first emitter electrodes **232** and four second collector electrodes **242**.

[0168] Upstream from each first electrode **232**, at a distance X2, is a third focus electrode **224**. Each third focus electrode **224a, 224b** (generally referred to as "electrode **224**") is at an angle with respect to a first electrode **232**. For example, the third focus electrode **224a** is preferably along a line extending from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**, as shown by extension line A. The third focus electrode **224a** is in-line and symmetrically aligned with the first electrode **232-1** along extension line A. Similarly, the third focus electrode **224b** is located along a line extending from middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-2**, as shown by extension line B. The third focus electrode **224b** is in-line and symmetrically aligned with the first electrode **232-2** along extension line B. As previously described, the diameter of each third focus electrode **224** is preferably at least fifteen times greater than the diameter of the first electrode **232**.

[0169] As shown in Fig. 12A, and similar to the embodiment shown in Fig. 6B, each second electrode preferably has a protective end **241**. In a preferred embodiment, the third focus electrodes **224** are electrically connected to the high voltage generator **170** (not shown). It is within the spirit and scope of the invention to not electrically connect the third focus electrodes **224** to the high voltage generator **170**.

[0170] Fig. 12B illustrates that multiple third focus electrodes **224** may be located upstream of each first emitter electrode **232**. For example, the third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1** along extension line A. Similarly, the third focus electrode **224b2** is in-line and symmetrically aligned with the third focus electrode **242b1** along extension line B. It

is within the scope of the present invention to electrically connect all, or none of, the third focus electrodes **224** to the high-voltage generator **170**. In a preferred embodiment, only the third focus electrodes **224a1**, **224b1** are electrically connected to the high voltage generator **170**, with the third focus electrodes **224a2**, **224b2** having a floating potential.

[0171] Fig. 12C illustrates that the electrode assembly **220** shown in Fig. 12A may also include a trailing electrode **245** downstream of each second electrode **242**. Each trailing electrode **245** is in-line with the second electrode so as not to interfere with airflow past the second electrode **242**. Each trailing electrode **245** is preferably located a distance downstream of each second electrode **242** equal to at least three times the width W of the second electrode **242**. It is within the scope of the present invention for the trailing electrode to by located at other distances downstream. The diameter of the trailing anode **245** is preferably no greater than the width W of the second electrode **242** to limit the interference of the airflow trailing off the second electrode **242**.

[0172] One aspect of the trailing electrode **245** is to direct the air trailing off the second electrode **242** and provide a more laminar flow of air exiting the outlet **260**. Another aspect of the trailing electrode **245** is to neutralize the positive ions generated by the first array **230** and collect particles within the airflow. As shown in Fig. 12C, each trailing electrode **245** is electrically connected to a second electrode **242** by a conductor **248**. Since the second electrode **242** is electrically connected to the high voltage generator **170**, the trailing electrode **245** is also negatively charged, and serves as a collecting surface, similar to the second electrode **242**, to attract the positively charged particles in the airflow. As previously described, electrically connecting the trailing electrode **245** generates negative ions to neutralize the positive ions emitted by the first electrodes **232**.

[0173] Fig. 12D illustrates that a pair of third focus electrodes **224** may be located upstream of each first electrode **232**. For example, the third focus electrode **224a2** is upstream of the third focus electrode **224a1** so that the third focus electrodes **224a1, 224a2** are in-line and symmetrically aligned with each other along extension line A. Similarly, the third focus electrode **224b2** is in line and symmetrically aligned with the third focus electrode **224b1** along extension line B. As previously described, and in a preferred embodiment, only the third focus electrodes **224a1, 224b1** are electrically connected to the high voltage generator **170**, while the third focus electrodes **224a2, 224b2** have a floating potential. It is within the spirit and scope of the present invention to electrically connect all, or none, of the third focus electrodes to the high voltage generator **170**.

<u>Electrode Assemblies With Second Collector Electrodes Having Interstitial Electrodes:</u>

<u>Figs. 12E-12F</u>

[0174] Fig. 12E illustrates another embodiment of the electrode assembly **220** with an interstitial electrode **246**. In this embodiment, the interstitial electrode **246** is located midway between the second electrodes **242**. For example, the interstitial electrode **246a** is located midway between the second electrodes **242-1, 242-2**, while the interstitial electrode **246b** is located midway between second electrodes **242-2, 242-3**. Preferably, the interstitial electrode **246a, 246b** are electrically connected to the first electrodes **232**, and generate an electrical field with the same positive or negative charge as the first electrodes **232**. The interstitial electrode **246** and the first electrode **232** then have the same polarity. Accordingly, particles traveling toward the interstitial electrode **246** will be repelled by the interstitial electrode **246** towards the second electrodes **242**. Alternatively, the interstitial electrodes can have a

floating potential or be grounded.

[0175] It is to be understood that interstitial electrodes **246a, 246b** may also be closer to one second collector electrode than to the other. Also, the interstitial electrodes **246a, 246b** are preferably located substantially near or at the protective end **241** or ends of the trailing sides **244**, as depicted in Fig. 12E. Still further the interstitial electrode can be substantially located along a line between the two trailing portions or ends of the second electrodes. These rear positions are preferred as the interstitial electrodes can cause the positively charged particle to deflect towards the trailing sides **244** along the entire length of the negatively charged second collector electrode **242**, in order for the second collector electrode **242** to collect more particles from the airflow.

[0176] Still further, the interstitial electrodes **246a, 246b** can be located upstream along the trailing side **244** of the second collector electrodes **244**. However, the closer the interstitial electrodes **246a, 246b** get to the nose **246** of the second electrode **242**, generally the less effective interstitial electrodes **246a, 246b** are in urging positively charged particles toward the entire length the second electrodes **242**. Preferably, the interstitial electrodes **246a, 246b** are wire-shaped and smaller or substantially smaller in diameter than the width "W" of the second collector electrodes **242**. For example, the interstitial electrodes can have a diameter of, the same as, or on the order, of the diameter of the first electrodes. For example, the interstitial electrodes can have a diameter of one-sixteenth of an inch. Also, the diameter of the interstitial electrodes **246a, 246b** is substantially less than the distance between second collector electrodes, as indicated by Y2. Further the interstitial electrode can have a length or diameter in the downstream direction that is substantially less than the length of the second electrode in the downstream direction. The reason for this size of the interstitial electrodes **246a, 246b** is so that the interstitial electrodes **246a, 246b**

have a minimal effect on the airflow rate exiting the device **100** or **200**.

[0177] Fig. 12F illustrates that the electrode assembly **220** in Fig. 12E can include a pair of third electrodes **224** upstream of each first electrode **232**. As previously described, the pair of third electrodes **224** are preferably in-line and symmetrically aligned with each other. For example, the third electrode **224a2** is in-line and symmetrically aligned with the third electrode **224a1** along extension line A. Extension line A preferably extends from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**. As previously disclosed, in a preferred embodiment, only the third electrodes **224a1**, **224b1** are electrically connected to the high voltage generator **170**. In Fig. 12F, a plurality of interstitial electrode **296a** and **246b** are located between the second electrodes **242**. Preferably these interstitial electrodes are in-line and have a potential gradient with an increasing voltage potential on each successive interstitial electrode in the downstream direction in order to urge particles toward the second electrodes. In this situation the voltage on the interstitial electrodes would have the same sign as the voltage on the first electrode **232**.

<u>Electrode Assembly With an Enhanced First Emitter Electrodes:</u>

<u>Figs. 13A-13C</u>

[0178] The previously described embodiments of the electrode assembly **220** include a first array of electrodes **230** having at least one wire-shaped electrode **232**. It is within the scope of the present invention for the first array of electrodes **230** to contain electrodes consisting of other shapes and configurations.

[0179] Fig. 13A illustrates that the first array of electrodes **230** may include curved wire-shaped

electrodes **252**. The curved wire-shaped electrode **252** is an ion emitting surface and generates an electric field similar to the previously described wire-shaped or rod-shaped electrodes **232**. Also similar to previous embodiments, each second electrode **242** is "downstream," and each third focus electrode **224** is "upstream," to the curved wire-shaped electrodes **252**. The electrical properties and characteristics of the second electrode **242** and the third focus electrode **224** are similar to the previously described embodiment shown in Fig. 6A. It is to be understood that an alternative embodiment of Fig. 13A may exclude the focus electrodes **224** and be within the spirit and scope of the invention.

[0180] As shown in Fig. 13A, positive ions are generated and emitted by the first electrode **252**. In general, the quantity of negative ions generated and emitted by the first electrode is proportional to the surface area of the first electrode. The height Z1 of the first electrode **252** is equal to the height Z1 of the previously disclosed wire-shaped electrode **232**. However, the total length of the electrode **252** is greater than the total length of the electrode **232**. By way of example only, and in a preferred embodiment, if the electrode **252** was straightened out the curved or slack wire electrode **252** is 15-30% longer than a rod or wire-shaped electrode **232**. The electrode **252** is allowed to be slack to achieve the shorter height Z1. When a wire is held slack, the wire may form a curved shape similar to the first electrode **252** shown in Fig. 13A. It is within the spirit and scope of the invention for the electrode **252** to be rigid. The greater total length of the electrode **252** translates to a larger surface area than the wire-shaped electrode **232**. Thus, the electrode **252** will generate and emit more ions than the electrode **232**. Ions emitted by the first electrode array attach to the particulate matter within the airflow. The charged particulate matter is attracted to, and collected by, the oppositely charged second collector electrodes **242**. Since the electrodes **252** generate and emit more ions than the previously described electrodes **232**, more particulate

matter will be removed from the airflow. The configuration shown in Fig. 13A may exclude the focus electrodes **224**.

[0181] Fig. 13B illustrates that the first array of electrodes **230** may include flat coil wire-shaped electrodes **254**. Each flat coil wire-shaped electrode **254** also has a larger surface area than the previously disclosed wire-shaped electrode **232**. By way of example only, if the electrode **254** was straightened out, the electrode **254** will have a total length that is preferably 10% longer than the electrode **232**. Since the height of the electrode **254** remains at Z1, the electrode **254** has a "kinked" configuration as shown in Fig. 13B. This greater length translates to a larger surface area of the electrode **254** than the surface area of the electrode **232**. Accordingly, the electrode **254** will generate and emit a greater number of ions than electrode **232**. It is to be understood that an alternative embodiment of Fig. 13B can exclude the focus electrodes **224** and be within the spirit and scope of the invention.

[0182] Fig. 13C illustrates that the first array of electrodes **230** may also include coiled wire-shaped electrodes **256**. Again, the height Z1 of the electrodes **256** is similar to the height Z1 of the previously described electrodes **232**. However, the total length of the electrodes **256** is greater than the total length of the electrodes **232**. In a preferred embodiment, if the coiled electrode **256** was straightened out the electrodes **256** will have a total length two to three times longer than the wire-shaped electrodes **232**. Thus, the electrodes **256** have a larger surface area than the electrodes **232**, and generate and emit more ions than the first electrodes **232**.The diameter of the wire that is coiled to produce the electrode **256** is similar to the diameter of the electrode **232**. The diameter of the electrode **256** itself is preferably 1-3mm, but can be smaller in accordance with the diameter of first emitter electrode **232**. The diameter of the electrode **256** shall remain small enough so that the electrode **256** has a high emissivity and is an ion